1985

Chemical, Sensory and Microbiological Properties of Water-added Ham Containing Pork and Turkey Blends

Chiao-min Chen

CHEMICAL, SENSORY AND MICROBIOLOGICAL PROPERTIES OF WATER-ADDED HAM CONTAINING PORK AND TURKEY BLENDS

BY

CHIAO-MIN CHEN

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science
Major in Animal Science
South Dakota State University
1985

CHEMICAL, SENSORY AND MICROBIOLOGICAL PROPERTIES OF WATER-ADDED HAM CONTAINING PORK AND TURKEY BLENDS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

K.W. Jones
Thesis Advisor

Date

John R. Romans
Head, Department of Animal and Range Sciences

Date

ACKNOWLEDGEMENTS

The completion of my Master's Program represented by this manuscript has been a result of the combined efforts of many people. It would not be feasible to acknowledge all those who contributed to my success, however some can not go unmentioned.

I express sincere appreciation to my advisor, Dr. Kevin W. Jones, for his assistance, guidance and encouragement throughout the entirity of my graduate study. Acknowledgement is given to Dr. William Costello, Dr. John Romans and Roger Johnson for their help and advice.

Thanks also to Mr. Leroy Warbog and his crew at the meat lab for the many hours of assistance and labor involved in this research. I am also indebted to the Departments of Animal & Range Sciences, Microbiology and Station Biochemistry for the equipment support and making this research possible.

I also wish to acknowledge Dr. W. Lee Tucker, with my sincere thanks for his assistance with the statistical analysis of this project.

To my parents, Mr. and Mrs. P. Chen, I extend my thanks and love for their support and guidance during my

life and college career. Mere words can't express the appreciation I have for them. To my sister and brother, Mrs. A.C. Chen and Mr. S.L. Chen, and my wife, Yi-Fang, whose encouragement throughout my graduate program have been invariable.

To these people and the others who have contributed to my success, I dedicate this thesis and share with them any sense of accomplishment.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	4
A. Sectioned and Formed Meat Products	4
Massaging and Tumbling	5
Particle Size	9
B. The Mechanisms of Protein Binding	10
Protein Extraction	14
Function of Proteins in Binding	16
Factors Affect Binding Strength	19
C. Ingredients & Functions in Sectioned and Formed Hams	24
Salt	24
Phosphate	26
Nitrite	28
D. Fat Oxidation	31
Microbial Spoilage of meat	36
E. Smoking	41
Thermal Processing	42
METHODOLOGY	47
Source of Meat	47
Processing Procedures	47
Laboratory Analysis	49

Cooking Yield 49
Proximate Analysis 50
Color Measurement 50
Thiobarbituric Acid (TBA) Analysis 51
pH Test 52
Microbial Analyses 53
Sensory Evaluation 53
Statistical Analyses 54
LITERATURE CITED 55
CHEMICAL AND SENSORY PROPERTIES OF WATER-ADDED HAM BLENDS CONTAINING PORK AND TURKEY THIGH MEAT ... 68
Abstract 69
Introduction 70
Materials and Methods 72
Results and Discussion 76
Conclusions 78
References 85
MICROBIOLOGICAL QUALITY AND STORAGE STABILITY OF WATER-ADDED HAM BLENDS CONTAINING PORK AND TURKEY THIGH MEAT 87
Abstract 88
Introduction 89
Materials and Methods 91
Results and Discussion 94

Conclusions 98

References 113

APPENDIX 115

PROCEDURE 1: TBA DETERMINATION 116

PROCEDURE 2: PIGMENTS DETERMINATION 118

FIGURE 1: CONSUMER TASTE PANEL SHEET 120

TABLE 1: THERMAL PROCESSING SCHEDULE 121

ANALYSIS OF VARIANCE TABLES 122

INTRODUCTION

In recent years there has been an increased consumption of convenience foods due to changing life styles and food distribution patterns. This trend will continue to have an influence on the meat industry. In response to these changes the meat industry has developed a great variety of processed products such as restructured steak, turkey ham, chicken loaves and turkey patties. In addition to previous changes, there are some economic factors which are responsible for shifts in consumption patterns from red meats to poultry meats. According to the Livestock and Poultry Outlook and Situation Report (USDA 1984), real disposable personal income in 1984 has risen nearly 6 percent from the previous year. In 1985, disposable personal income may rise at about one-half the 1984 rate. However, consumers are expected to remain price-conscious, helping the demand for poultry, which is lower priced than most red meat products. In response to these changes the meat industry is challenged to begin the best long range plans possible to meet new market demands.

The production of sectioned and formed ham products, made by mixing large chunks of muscle and molding these

chunks into one homogenous meat block of desired shape and texture, has become popular with the meat industry. The consumption of sectioned and formed product in today's society is becoming increasingly popular owing to the intrinsic advantages of this type of product, such as easier and more accurate portion control, simulation of boneless high quality cuts, improved efficiency, improved tenderness, and decreased processing time.

Therefore, the primary reason for the meat industry manufacturing products of this type is that these products are uniform in color, texture and fat distribution and can be marketed in virtually any shape or form. Profit margins may be increased due to reduced shrink and cook loss and by incorporation of some of the lower value muscles into a product of higher value. The binding of the muscle chunks into a uniform, cohesive meat block is what makes this process practical from an economic and production standpoint.

Recent economic surveys have indicated that consumers spend more time in choosing their food products than in the past. With tighter budgets and the consumer's growing antagonism toward higher food prices, it is clear that if a cheap and good quality restructured meat product is to

appeal to consumers, it must meet their standards.

The partial replacement of pork with turkey thigh meat making a combined ham is a new product for consumers. Several advantages can be predicted from research in this area: it (1) provides a more economical ham to the consumers (2) decreases fat content (3) increases nutritive value (high protein content) and (4) increases the value of the lower-valued turkey thigh meat.

The objectives of this research are:

(1) To determine chemical and organoleptic properties of pork and poultry blend hams.

(2) To examine microbiological and shelf-life properties of this vacuum-packaged ham.

(3) To develop a high quality, economical product.

REVIEW OF LITERATURE

Sectioned and formed meat products

Sectioned and formed (S/F) meat products are produced by binding large pieces or chunks of meat together to resemble a continuous whole meat mass.

The production of sectioned and formed meat products has become increasingly popular in the poultry and red meat industries. These products have gained consumer acceptance and are manufactured by processes which are inherently advantageous to processors. These processes are collectively referred to as tumbling or massaging (Anonymous, 1971; Weiss, 1973; Schmidt, 1977; Schmidt and Siegel, 1978).

Sectioned and formed meat products are made by mechanically treating meat pieces to disrupt the normal muscle cell structure. This produces a creamy, tacky protein exudate on the surface of the meat pieces. This exudate binds the meat pieces when heated to produce a cohesive, formed product of improved quality and tenderness while maintaining the texture and appearance of intact muscle. Mandigo (1982) stated that sectioned and formed products have a more desirable intact muscle-like texture than flaked products.

Massaging and Tumbling

The mechanical action required to produce high quality S/F meat products may be achieved in a variety of ways, which may churn, tumble, pound or massage the muscle chunks, but most commonly involves the process of tumbling or massaging. Both methods subject meat chunks to manipulation and abrasion in a massager or tumbler and make the chunks soft and pliable. This mechanical action in the presence of salt produces a tacky exudate on the surface of the meat chunks. The resultant product displays similar chemical, physical and organoleptic properties to that of intact muscle. Massaging and tumbling are utilized in the production of sectioned and formed hams, roasts or rolls from pork, beef and poultry meat (Schmidt, 1977).

The physical treatment resulting from tumbling and massaging is different in nature. Tumbling, as defined by Cassidy et al. (1978), involves the physical process of meat rotating in a drum, falling and making contact with metal walls and paddles. The mechanical energy produced in tumbling processes is a result of the impact energy of meat pieces falling from the top of a rotating drum. The tumbling treatment is most effective when applied to firmer muscle tissue such as beef, turkey and mutton.

Massaging, on the other hand, is a less severe treatment than tumbling. Massaging refers to the action of a slow verticle mixer designed to act gently and stir large chunks of meat (Schmidt, 1977). Frictional energy is generated from the process of massaging through the abrasion of meat pieces being rubbed and massaged against each other. Massaging action is most appropriately applied to soft muscle tissues such as pork and chicken.

Both processes employ mechanical agitation to promote the formation of a protein exudate which enhances muscle cohesion properties (Fukazawa et al., 196la,b). Tumbling or massaging action also aids in the rapid diffusion of curing pickle (Krause et al., 1978b; Ockerman and Organisciak, 1978) and results in a more uniform product color. Krause et al. (1978a) also reported that tumbling significantly improved the external appearance, color, sliceability and yield of cured hams.

Maesso et al. (1970) observed that mechanical beating of chicken meat for 3 min released the intracellular contents from broken muscle cells and caused a significant increase in binding characteristics.

Using scanning electron microscopy, Theno (1977) and Theno et al. (1978a,b,c) examined the massaged muscle chunks and actually observed that myofibrils are disrupted

as a result of massaging. Cassidy (1977) and Cassidy et al. (1978) reported that tumbling increases cell membrane disruption, disorganization of cell nuclei and decreases the clarity of muscle striations.

Krause et al. (1978a) found that tumbling for 10 minutes out of each hour for 18 hours at room temperature resulted in increased migration of salt and nitrite into semimembranosis muscles as compared to non-tumbled muscles and resulted in a significant increase in color development.

Knipe et al. (1981) reported that tumbling and phosphate addition significantly improved the yield of boneless, cured, cooked hams. They also found tenderness was slightly improved by tumbling. Vartorella (1975) did not find significant improvements in sensory panel tenderness of canned, cured hams due to tumbling. However, Warner-Bratzler Shear tenderness was improved by the tumbling process.

Babji et al. (1982) observed that tumbled turkey meat had higher pH values and lower cooking losses than non-tumbled turkey meat. They also stated that there were no significant differences in chemical composition of the tumbled salted, tumbled unsalted, nontumbled salted, and nontumbled unsalted turkey breast meat. A slightly higher

but nonsignificant moisture content was observed for the tumbled samples. The ash, fat, and protein content were essentially the same in the four treatments.

Reported tumbling time requirements needed to reach cure penetration vary from 30 minutes continuously to 18 hours intermittently. During this processing period, there are several opportunities for increasing the contamination by microorganisms on the surface or subsurface of the meats. Ockerman and Kwiatek (1984) observed that tumbling and processing time caused an increase in Lactobacillus Plantarum levels when innoculated in the muscle.

Mills et al. (1980) reported that neither surface nor subsurface total plate counts of cooked hams were affected by tumbling processes (10 min/hr for 18 hr at 3 °C). Knipe et al. (1981) found that processing temperature affected final cooked yield independent of tumbling. He also reported that tumbling temperature affected both internal color and tenderness. Processing at room temperature significantly improved the internal color of the final cooked product. In an attempt to cure meat quickly, a temperature above refrigerated temperatures would be expected to increase the rate of cure migration. But it might reduce the shelf life of products.

Ockerman and Kwiatek (1984) reported that tumbling

resulted in higher numbers of microorganisms in the internal tissue of product tumbled 18 hr at 23°C than at 3°C. This finding would be expected since growth conditions of microorganisms are nearer their optimum.

It is evident that influences of massaging and tumbling on the meat characteristics are dependent upon a number of variables such as processing time, temperature, levels of phosphate and salt added etc., and their possible interactions.

Particle Size

Acton (1972b) found that reducing the particle size increased the amount of salt-soluble protein extracted. With such an increase in protein extraction, there is an increase in binding strength. This relationship between bind strength and exudate volume was highly correlated (r=0.91).

Acton (1972a) investigated the functional properties of the protein exudate formed by meat mixing and concluded that the surface proteins reduced cook losses and increased binding strength. The amount of myofibrillar protein present in the exudate could be increased by decreasing muscle particle size with a resultant increase in surface area.

Chesney et al. (1978) reported that cooking losses decreased with decreasing particle size. Durland et al. (1982) stated that overall appearance ratings generally decreased as particle size increased. However, these latter two studies did not involve tumbled or massaged sectioned and formed products which are generally stuffed in a casing or cook in bag.

Mechanisms of Protein Binding

Binding of meat chunks is extremely important in the production of restructured meat products. Schnell et al. (1970) reported that binding is a complex phenomenon involving water binding, cellular disruption, the release of intracellular materials, and physical and chemical changes in the salt-soluble proteins produced by heating. Vadehra and Baker (1970) concluded that binding between chunks of meat is a phenomenon involving structural rearrangement of the solubilized meat proteins.

The binding process also involves a complex interaction between water binding, cellular disruption, and physical and chemical changes in the muscle proteins through heat denaturation (Rahelic et al.,1974). The protein coagulates and the muscle pieces are held together by a loose protein matrix of realigned myofibrillar

proteins, connective tissue, fat, and water (Kotter and Fisher, 1975).

The mechanism of gelation appears to be related to two separate physical phenomena: (1) protein denaturation; and (2) protein aggregation (Ferry, 1948). Hermansson (1978) stated aggregation of the protein molecules is random, whereas, gelation involves the formation of a continuous network exhibiting a certain degree of order. When aggregation is suppressed prior to denaturation, the resulting network can be expected to exhibit a higher degree of elasticity than if random aggregation and denaturation occur simultaneously, or if aggregation precedes denaturation.

Myosin, the most important meat protein involved in binding reactions, contains a long tail consisting of two super-coiled alpha-helical polypeptide chains (heavy chains). The head of the molecule is composed of four short chains (light chains). The myosin molecule can be fragemented by the action of proteolytic enzymes. Trypsin cleaves the myosin molecule into long rod-like light meromyosin (LMM) and heavy meromyosin (HMM). This last portion can be further subdivided by papain into the globular subunit S1 and the helical rod S2 (Bodwell and McClain, 1971; Lehninger, 1982; and DeRobertis and

DeRobertis, 1980).

Hamm (1966) concluded that high temperatures, characteristic of cooking, cause the proteins to change into a random coil-type configuration. Different conformational changes in the muscle proteins occur upon the absorption of thermal energy and are measured according to transition temperatures. Burke et al. (1973) reported that the first of two transition temperatures (44 °C), is the result of a helix-coil transformation in the trypsin-sensitive "hinge" region of the myosin rod. The second transition temperature (55 °C) was assigned to a similar transformation in the remaining LMM segment.

Samejima et al. (1981) proposed that the heat-induced gelation of myosin, consists of two reactions: (1) aggregation of the globular head segments of the myosin molecules, which is closely associated with the oxidation of sulfhydryl groups; and (2) network formation resulting from the unfolding of the helical tail segment and the head portions to form super-junctions which provide extra cross-linking to the gel network.

Denaturation studies on myosin reported by Yasui et al. (1966) and Kawakami et al. (1971) indicated that the aggregation of myosin molecules was due to fusion of the head portion of the molecules by heat, which took

place at a temperature around 35 °C.

Samejima et al. (1976) stated that thermal denaturation of the myosin tail portion results from the disruption of stabilizing forces of a noncovalent nature, such as hydrogen bonds and hydrophobic interactions, and that disulfide cross-links or other covalent bonds are not involved.

Yasui et al. (1979) made the following conclusions concerning the gelation of myosin: (1) the thermal transition from sol to gel begins at 30 °C and reaches a maximum at 60 - 70 °C; (2) on the basis of nuclear magnetic resonance (NMR) spin-spin relaxation times, the mobility of the water within the gel network is more restricted than that of free water; and (3) the properties of the gel network are dependent upon pH.

A possible conclusion may be found in the research of Acton (1984) for the explanation in results between protein-protein interactions of binding development. Acton (1984) concluded that aggregation involved the head portions of myosin at temperatures between 30 °C and 50 °C and the rod segment in the temperature region above 50 °C. Some initiation of conformational changes occur in the rod segment in the lower temperature zone due to the

sensitivity of the "hinge" region connecting the S-2 and LMM segments. The complete myosin molecule is necessary for attaining appreciable continuity and strength in the protein matrix.

PROTEIN EXTRACTION

The mechanical disruption of fiber structure is characterized by breakage of the sarcolemma and a longitudinal separation of the myofibrils from one another. The development of spaces between the myofibrils and the destruction of the fiber membranes results in a greater surface area becoming available for protein extraction.

The exudate is principally a solubilized protein suspension containing the myofibrillar proteins (Schnell et al., 1970; Acton, 1972a, b). The exudate is not exclusively composed of solubilized myofibrillar protein, it also contains fat, water, and pieces of broken muscle fibers (Rahelic, 1974; and Siegel et al., 1978a).

The massaging process serves to disrupt the normal muscle structure, creating a greater surface area from which greater amounts of myofibrillar proteins may be extracted. These solubilized proteins are thought to be released either through extraction from muscle cells or by

cellular disruption resulting in a release of intracellular materials into the exudate. The protein-rich exudate has been shown to be highly concentrated between the muscle pieces in chunk-type products (Schnell et al., 1970; and Vadehra and Baker, 1970).

Macfarlane and McKenzie (1976) showed that myofibrillar protein could be extracted by subjecting muscle fibers to high pressure. The disruption of normal structure and integrity results in the muscles losing their normal firmness and they become soft and easily formed into desired shapes.

The massaging process disrupts the muscle thereby increasing total surface area. However, the massaging process does not adequately solubilize the myofibrillar proteins. The action of salts and phosphates in extracting myofibrillar proteins is well documented. The massaging process simply serves to increase the surface area available for protein extraction by the salts and phosphates (Theno, 1977).

The effect of vacuum and extraction time on the extractibility of crude myosin from pre- and postrigor meat was studied by Solomon and Schmidt (1980). They concluded: (a) the extraction of crude myosin increased linearly with extraction time; (b) vacuum

increased the amount of crude myosin extracted by 20% over that of the non-vacuum treatment; and (c) 65% more crude myosin was extracted from prerigor meat than from postrigor meat. Saffle and Galbreath (1964) and Acton and Saffle (1969), both found that the amount of salt-soluble protein extracted from prerigor meat was approximately 50% greater than that extracted from postrigor meat.

Siegel and Schmidt (1979) found that increasing the amount of extracted myosin between meat surfaces produced a linear increase in binding strength in a model binding system. Randall and Voisey (1977) found that when as little as 2.5% of the total protein was replaced with salt-extracted proteins, the binding strength of the resultant product increased.

Function of Proteins in Binding

Binding pieces of meat together to produce a unit system is initiated by the formation of mechanical binding ability between the proteins (Macfarlane et al., 1977). The importance of salt-soluble proteins and their role in bond formation is of great consequence regardless of the type of meat. Binding properties appear to be the result of an interaction of fat and water as well as protein (Vadehra and Baker, 1970). The cohesive substance that formed the bond is the exudate and, as mentioned previously, it is formed by subjecting the meat pieces to

physical or mechanical treatment. Restructured products require that muscle proteins be extracted to the surface of the meat particle so protein interactions between particles can occur. Proteins serve to glue chunks of meats together and produce a unit system.

Muscle proteins can be divided into three general catagories: (1) Sarcoplasmic, the metabolic proteins; (2) Stromal, the connective tissue proteins; (3) Myofibrillar, the contractile element proteins. Each of these fractions of muscle proteins may contribute to final product characteristics.

The sarcoplasmic proteins account for 20 to 30% of the total muscle protein. Characteristically, these proteins are the most easily extracted and are classified as the "water soluble" proteins since they can be extracted with very low ionic strength solutions. Fukazawa et al. (1961a) reported that the water soluble proteins had hardly any influence on the binding quality of meat. It was concluded by several scientists that water soluble proteins exert little influence on binding (Maurer et al., 1969; Acton and McCaskill, 1972 and Reynolds et al., 1978). Siegel and Schmidt (1979) found that even when sarcoplasmic proteins were completely removed, there was no significant increase in binding ability in the presence of 6% salt and 2% sodium tripolyphosphate. However,

Schmidt and Trout (1982) stated the sarcoplasmic proteins make a significant contribution to the meat binding ability when the ionic strength of binding matrix is low (below 0.4 M).

Stromal proteins, which include collagen, elastin and reticulin, are not salt soluble and thus remain in the residue of muscle tissue extracted with strong salt solution. Because of the structural integrity of its matrix formation, collagen can contribute considerably to final product texture. Collagen undergoes thermal shrinkage upon heat treatment and converts to gelatin upon prolonged, moist-heat treatment. This characteristic makes collagen a poor binding agent in heat-processed emulsion products.

The myofibrillar proteins make up 60% of the total muscle proteins. The primary proteins are myosin (50-55%), actin (15 - 20%), tropomyosin, troponin and actinin. Myofibrillar (salt-soluble) proteins play a major role in the binding of meat products. In characterizing the role of specific myofibrillar proteins in meat binding, Macfarlane et al. (1977) reported that the binding ability of myosin is best with NaCl concentrations below 1.0 M; at salt concentration of 1.2 M or 1.4 M, actomyosin had an equal bind to that of myosin. Fukazawa et al. (1961a,b) found that myosin and actomyosin had a great influence in

the formation of the bond. Acton (1972b) found that an increase in salt soluble protein extractability and the increase of binding strength were significantly correlated. Galluzzo and Regenstein (1978) found that myosin is the most rapidly solubilized protein and forms thick, creamy emulsions in model systems. Schmidt and Siegel (1978) found that myosin alone bound pieces of meat together quite well. Binding was enhanced by the increased extraction of myosin with the use of salt, phosphate and mechanical action.

Nakayama and Sato (1971a, b) and Samejima et al. (1969) agree that myosin and actomyosin contribute the most to the development of the binding phenomena.

FACTORS AFFECTING BIND STRENGTH

Bard (1965) reviewed some factors influencing the extractability of salt-soluble proteins from muscle tissue and concluded: (1) temperature in the range of $-5^{o}C$ to $2^{o}C$ gave maximum protein extraction; (2) increasing extraction time increased protein extraction, up to an extraction time of 15 hr; (3) proteins in pre-rigor meat are more extractable than postrigor meat. In addition to previous factors, there are other factors which influence the extractability of salt-soluble proteins such as ionic strength, pH, and particle size etc..

Product bind which results from tumbling or massaging is not produced by the mechanical treatment alone, but with the addition of salt, alkaline phosphate and/or non-meat protein binders. Maesso et al. (1970) showed that mechanical action, salt and phosphate enhance the extraction of salt-soluble protein and results in a significant increase in binding of meat pieces into a unit system.

Salt. Schmidt and Trout (1982) stated the mechanisms by which salts increase the binding ability of the protein matrix are: (1) by increasing the amount of a protein extracted; and (2) by altering the ionic and pH environment so that the resultant heat-set protein matrix forms a coherent 3-dimensional structure. Turner et al. (1979) found that increasing the concentration of salt in crude myosin preparations resulted in an increased binding strength.

Phosphate. The addition of alkaline phosphates has been shown to have the greatest single effect on the relative percentages of myofibrillar proteins in the exudate of massaged hams (Siegel et al., 1978b). Alkaline phosphates aid in the solubilization of proteins even without salt. Siegel et al. (1978a) found massaging had no significant effect on losses from cooking, however, yield improvements were observed with the addition of phosphate. Hamm (1970)

demonstrated that the addition of salts and certain phosphates increased the water holding capacity (WHC) in meat. Phosphate also facilitates extraction of the myofibrillar proteins through the sarcolemma.

A synergistic effect is observed when salt is combined with alkaline phosphates resulting in greater yields and myofibrillar protein solubilization. At the levels of salt and phosphate used in the production of sectioned and formed meat products, the salt concentration increases ionic strength enough to spread the filaments but does not cleave the crossbridges. Phosphates resolve the actomyosin structure but may not increase ionic strength enough to spread the filaments (Mahon, 1961).

Temperature. Binding of muscle pieces actually occurs during the heat treatment and is very important to the quality of a sectioned and formed product. Vadehra et al. (1970) stated that salt-solubilized proteins may not be of sole importance in binding meat pieces together. Rather, cooking temperature was reported to have a significant effect when the meat was heated for long periods at low temperature; the best bind was found at 65 ^{o}C and 75 ^{o}C, for 40 - 50 minutes.

Acton (1972a) investigated the effect of heat processing on the binding strength and cook loss of poultry meat loaves. There was no appreciable binding

below 35°C, and above 82°C the binding strength decreased. He also reported the percent of extractable protein was significantly reduced as higher internal temperatures were attained during the cooking process. There was no significant change in the quality of protein extracted between 4 and 35°C while the most significant decrease in extractability occured between 35 and 75°C.

Binding strength is also dependent upon the meat temperature during tumbling or massaging. Salt soluble proteins are most readily extracted from lean meat at 36 to 38°F (2.2 - 3.3°C). This supports the findings that the bind strength of ham was much better when massaged at 30°F and 40°F (-0.9°C and 4.4°C) than at 50°F (10°C) (Knipe, 1982).

pH. The binding of meat pieces is also affected by the pH of the muscle. Heat initiated binding of muscle pieces is improved with higher pH's. Myosin is optimally solubilized at pH 6.5. Saffle and Galbreath (1964) stated that pH of the meat has a significant effect on the amount of salt-soluble protein which can be extracted. Increasing the pH has been shown to increase the solubility of myofibrillar proteins. Bard and Townsend (1971) observed that the solubility of salt-soluble proteins are greatly

influenced by pH and ionic strength. Increasing pH and salt separately or in combination will increase the solubility of myofibrillar proteins.

Processing Time. Binding strength also increases with longer massaging or blending times. This is due to increased exudate formation on the surface of the meat. Crude myosin extraction is increased with increased blending time. Siegel et al. (1978a) reported that the minimum massaging time needed to produce a statisfactory sectioned and formed product that exhibits acceptable binding properties is 8 hours. Gillett et al. (1981) also reported that by increasing massaging time, binding strength was improved.

Particle Size. Binding strength is also increased with decreasing meat particle size. More surface exudate is produced as the meat surface area increases. This is due to increased cellular disruption resulting from cutting intact muscles and releasing cellular contents.

Acton (1972b) found that reducing the particle size increased the amount of salt-soluble protein extracted. With the increase in protein extraction, there was a concurrent increase in binding strength and the relationship between them was significant and highly correlated (r=0.91).

Vacuum Mixing. Vacuum tumbling or mixing, improves bind strength by reducing protein foaming. Foaming denatures proteins and, subsequently, decreases bind strength. Vacuum has been credited with increasing the amount of protein extracted and decreasing the time required to produce the optimal product bind.

Solomon and Schmidt (1980) found there was a significant increase in the amount of crude myosin extracted under a vacuum mixing system, but the total amount of protein extracted was not affected. It has been reported that 20-30% more protein is extracted in a vacuum chopper as opposed to an open bowl chopper (Annonymous, 1978).

Ingredients and Functions in Sectioned & Formed Hams

Salt The major functions of salt in sectioned and formed products are 1) flavor; 2) extraction of salt-soluble proteins; 3) altering the ionic strength and pH; 4) slight tenderness advantages and 5) preservative properties.

Salt is used primarily for its flavor effect on meat products. Mandigo et al. (1973) and Neer and Mandigo (1974) reported that consumers prefered salted products to nonsalted products. The most important function of salt (NaCl) may be its ability to extract the myofibrillar

proteins which results in a increase in the binding quality of processed meats.

The role of salt is also to contribute to the ionic strength of the system, the other role is to alter the pH. The mechanism of increased water holding capacity upon sodium chloride addition was described by Hamm and Deatherage (1960) and Schut (1976). The chloride ion was bound to the protein's positive charged group involving most of the exposed groups. Sodium was only weakly bound to the negative charges. The overall effect was such that structured phosphate are able to break the linkage between peptide chains and filaments resulting in an increased space between the filaments at or above pH 5 and increased the protein molecule's ability to bind or hold water.

Salt has also been related to tenderness in meat products. Szczesniak and Torgeson (1965) observed that sodium chloride concentrations of 2% will appreciably increase beef tenderness.

The preservative properties of salt are due to the compound's osmotic ability of lowering the water activity (Aw) of the fluid in the meat (Wilson 1981). Reductions of Aw inhibit microbial growth rates and metabolic activities of bacteria. Water activity is defined by Romans et al. (1985) as:

$$\text{Water Activity (Aw)} = \frac{\text{Vapor pressure of solution}}{\text{Vapor pressure of pure water}}$$

Phosphate The principle functions of phosphates in sectioned and formed meat products are 1) water retention; 2) slight color stabilization advantages; 3) slight antioxidant properties and 4) improved product bind (discussed previously).

Phosphates are primarily utilized in the processing of meat products due to their influence on water contained in or added to the meat. Alkaline phosphates cause retention of moisture in raw meat and limited the amount of moisture lost through heat processing. Brahms and Brezner (1961) concluded that the binding of polyphosphate ions in the basic range of the isoelectric point must bring about an increase of the negative net charge of myofibrillar proteins and thus an increase of the electrostatic repulsion between adjacent protein filaments. Therefore, more water can be immobilized within the loosened structure of the protein. Polyphosphates are efficient complexing agents of calcium ions (Wierbicki et al., 1976). They suggested that polyphosphates function as chelating agent by binding positively charged calcium ions from the meat tissue, which are involved in cross-

bridges between muscle filaments. The net result is an increase in space between filaments, leaving more available space for water. Thus, chelation of calcium ions by polyphosphates will allow a greater uptake of water.

Schmidt and Siegel (1978) found that massagng had no significant effect on cooking losses. However, the cooking yields were much higher in the treatments with the added phosphate. Wierbicki et al. (1976) reported that use of 0.3% instead of 0.5% TPP in cured ham meat was sufficient for the purpose of shrink control.

Szent-Gyorgyi (1952) speculated that the biochemical reason for the effect of phosphates on the tenderness of any meat product relates to the ability of phosphate to inhibit the formation of actomyosin and thus increase tenderness. Ockerman et al. (1978) reported that phosphates caused a slightly lower shear value when used with salt in short tumbled and cured pork.

Other benefical actions of phosphates have been reported. Krause et al. (1978b) found that the interaction of phosphates and tumbling aided in the development of stable cured meat color at reduced levels of sodium nitrite. The cured meat color was enhanced by the increased migration of salt or sodium tripolyphosphate alone or in combination. Phosphates have also been

reported to improve external color as well as flavor and aroma (Krause et al., 1978a).

Rahelic et al. (1966) noted that when phosphate was used in a brine containing nitrite, the pH values increased significantly in the cured meat system, also the nitroso pigments were increased significantly when compared to samples prepared from a brine containing no phosphate.

Polyphosphate added to chicken meat that is cooked and stored at refrigerator temperatures has been found to protect the meat from oxidative deterioration (Shults and Wierbicki, 1973; Thomson, 1964). Tims and Watts (1958) reported that tripolyphosphate protected the cooked pork against development of oxidative rancidity.

Nitrite Color, flavor, protection from oxidation and inhibition of microbial growth are the major functional contributions of nitrite to cured meat.

Color development of cured products is stabilized by the action of nitric oxide bound to the heme group of the myoglobin molecule. The heme group is composed of an organic ring structure, protoporphyrin, and an iron atom. The iron atom has six coordination bonds, four to the porphyrin molecule and two perpendicular to it. The latter bonds are termed 5th and 6th coordination positions. The 5th-position is bound to the globin component of the myoglobin molecule. The 6th-position is open to serve as a

binding site for oxygen, carbon dioxide, nitric oxide or other compounds (Lehninger, 1982). Giddings (1977) stated that the 6th-position ligand of cured meat myoglobin is nitric oxide, which binds to the heme iron via the nitrogen atom to form an extremely stable paramagnetic adduct. The characteristic bright red color of uncooked cured meat is due to the interaction of nitrite with myoglobin of meat to form the nitroso-myoglobin pigment. Upon heating, the color changes to the characteristic stable cured color whose intensity of redness is determined by the myoglobin content of the muscle. Fox (1966), and Sebranek (1980) described the role of nitrite in fixing and stabilizing the typical cured meat color. Krause et al. (1978a) stated that tumbling causes a disruption of the sarcolemma, and myoglobin from within the muscle fiber is more quickly available to the nitrite in the spaces between the cells for the more rapid development of an acceptable color.

Cho and Bratzler (1970) reported that pork roasts cured with sodium nitrite had more cured flavor than smoked samples cured without nitrite.

The anti-bacterial activity of nitrite is due to undissociated HNO_2. In a study by Castellani and Niven (1955), a possible explanation was offered involving growth inhibitions imposed by nitrite. These are: (1)

nitrite inhibits organisms known to be devoid of heme-containing respiratory catalysts; (2) nitrite reacts with sulfhydryl constituents and sulfhydryl-aldehyde condensations not metabolizable under anaberoic conditions. Zottola (1972) reported nitrite decomposed to yield nitric oxide (NO) which has some inhibitory effect on anaerobic organisms.

Castellani and Niven (1955) reported the microbial inhibitory effect of nitrite was strongly dependent on pH and, at the concentration permitted in meat, less nitrite was necessary for inhibition as the pH decreased from 6.9 to 5.0.

Bushway et al. (1982) stated that nitrite concentrations of 100 and 150 ppm lowered the total number of aerobic microorganisms developing in poultry raw white meat patties, but were not effective in raw dark meat patties (400 ppm was required to repress growth of aerobic microorganisms).

Zabillaga et al. (1984) observed that residual $NaNO_2$, carbon-nitroso and nitrogen-nitroso compounds, or, products of the additions of nitrogen oxides to olefins, do not seem to account for the antioxidant activity of linoleic acid oxidation. Cross and Ziegler (1965) concluded that nitrite minimizes the oxidation of

unsaturated lipids. Hadden et al. (1975) stated that nitrite can retard the rate of oxidative rancidity (TBA value) in comminuted pork. Sato and Hegarty (1971) suggested that nitrite might inhibit natural prooxidants present in muscle or stabilize the lipid compounds of the membrane. In a study of turkey ham properties by Hasiak et al. (1984), it was reported that the presence of either nitrite or erythorbate significantly decreased the TBA value. Total pigment levels of the turkey hams decreased significantly during storage and were directly related to initial nitrite levels. They also indicated that products containing nitrite at levels of 78, 104 and 156 ppm had a shelf-life of 2 to 4 weeks longer than the products containing nitrite at levels of 0 and 52 ppm.

Fat Oxidation

The oxidation of food and food products and the development of rancid flavors is partially due to the presence of unsaturated fatty acids. Generally speaking, the higher the proportion and degree of unsaturation of the fatty acids, the more liable the lipid system is subject to oxidation. Chen and Waimalenogoraek (1981) reported poultry meat contain a higher proportion of unsaturated fatty acid than the fat from red meat. The

lower pH value of the meats was also thought to accelerate an increase in TBA values. TBA number refers to the mg of malonaldehyde per 1000 g of meat and is a common measure of rancidity.

Moerck and Ball (1974) reported that highly unsaturated fatty acids in the phospholipid fraction appeared to be responsible for the development of oxidative rancidity. This oxidative deterioration of muscle lipid involves oxidation of the unsaturated fatty acids, particularly the polyunsaturated fatty acids (Allen and Foegeding, 1981). The polyunsaturated fatty acids which have three or more double bonds and are associated with the phospholipids are critical in the development of off-flavor in muscle.

The mechanism of autoxidation involves three stages.

1. Initiation : $RH + O_2 \longrightarrow R. + .OH$

2. Propagation: $R. + O_2 \longrightarrow RO_2.$

$$RO_2 + RH \longrightarrow RO_2H + R$$

3. Termination: $R. + R. \longrightarrow RR$

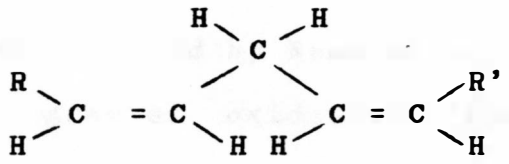
$$R. + RO_2 \longrightarrow RO_2R$$

$$RO_2. + RO_2. \longrightarrow RO_2R + O_2$$

The possible structural changes involved in autoxidation are shown as Figure 1. (Fapojuwo, 1981).

Figure 1. Reaction mechanisms for the autoxidation of an unsaturated fatty acid.

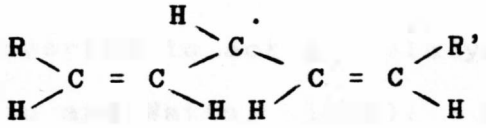
(1)



Unsaturated Fatty Acid

Abstraction of a hydrogen atom from the methylenic carbon atom adjacent to a double bond.

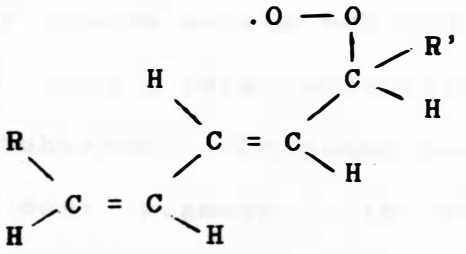
(2)



Free Radical

The free radical then reacts with molecular oxygen to form a hydroperoxy radical.

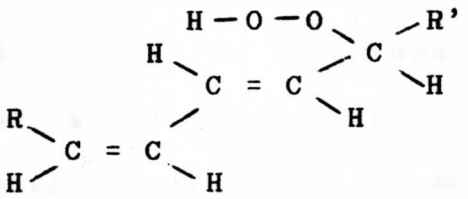
(3)



Hydroperoxy Radical

Addition of hydrogen abstracted from another fatty acid.

(4)



Hydroperoxide Product

Source: Fapojuwo, 1981.

A study reported by Kemp et al. (1961) showed that hams with greater oxidative rancidity had lower palatability scores. Thus, the reduction of oxidative rancidity would have a desirable effect on the acceptance of these hams.

Numerous compounds, including heme and nonheme iron, have been reported to act as catalysts of lipid oxidation in meats (Liu and Watts, 1970). However, cured meats may be held at refrigerator temperatures for a much longer period of time than uncured meats before tissue rancidity is noted. It was considered that differences in the heme pigments of cured versus uncured cooked meats might be responsible for this observed difference in their oxidative behavior. Younathan and Watts (1959) reported the cured meat pigment, in which the 5th and 6th coordination sites of the iron are occupied by denatured globin and nitric oxide, respectively, would not be

expected to react as a fat peroxide in the manner postulated for hematin or hemoglobin. Oxidative reactions occur less rapidly in cured meats which retain their pink color. It might be expected that oxidation of the cured meat pigment to the ferric form would result in catalysis of fat oxidation. Ferric hemochrome is an active catalyst for unsaturated fat oxidation, whereas ferrous nitroso hemochrome is not. This paper also reported that the ferric form of the pigment is the active catalyst in tissue rancidity. Uncured cooked meat, which contains ferric denatured globin hemochrome, showed high TBA values shortly after cooking. No such increase was noted in a cured meat sample in which the pigment was present as pink ferrous nitroso hemochrome. When brown ferric oxidation products appeared upon subsequent storage of the cured meats TBA values increased. Rancid odors which develop in stored cooked meat were found to correlate with an increase in TBA values. Zisper et al. (1964) reported that the ratio of peroxides to TBA number was 8 to 10 times as high in cured as in uncured meats. It is proposed that nitrite reacts with heme-containing proteins to form catalytically inactive species.

The pH value of the products is one of the many factors reported to affect the rate of lipid autoxidation.

Marbrouk and Dugan (1960) reported that the oxidation rates of methyl linoleate emulsions increased with an increase in the pH of the buffer solution.

Zisper et al. (1964) found that the rancid odor showed a highly significant correlation (r=0.92) with TBA number in both cured and uncured meat. Pigment losses in cured samples were correlated with both peroxides and TBA number (r=0.87).

Vacuum-packaged cured meat is claimed to have better quality than meat packed at atmosphere pressure. First, the natural color resists change better, for the change in color of cured meat products are essentially dependent on oxygen. Also, oxidative rancidity is dependent on oxygen and therefore it is retarded after the oxygen is depleted from the package. Lin et al. (1980) reported the high vacuum levels showed lower TBA numbers, and superior color retention. Vacuum packaging has thus become the most popular method used to limit oxygen availability in processed meat.

Microbial spoilage of meat

Processed meat products are commonly stuffed and cooked in relatively impermeable casings and are not subject to internal contamination during handling subsequent to cooking. Contamination of such products can be caused only

by organisms that survive the process or by contaminations growing on the surface.

In practice, the actual storage life will be influenced by factors such as the pH, water activity, initial microbial load on the meat, temperature of storage, etc..

Microbial growth increases with both increased pH and a high water-activity level. The addition of phosphates could very likely result in an increase in microbial numbers (Lechowich, 1971). The storage of muscle food is normally controlled by the use of low temperature storage in combination with packaging. However, the shelf-life of refrigerated products is still limited as a result of oxidative rancidity, especially uncured products.

The predominance of lactic acid bacteria in cured meat products has been widely reported. The organisms found to be most numerous in vacuum packaged luncheon meats were lactic acid bacteria (Kempton and bobier, 1970). In 1960, Allen and Foster plotted the growth of bacteria in vacuum-packaged sliced processed meats during refrigerated storage. They found that lactic acid bacteria were the only organisms capable of proliferating rapidly in this environment.

Spoilage of cold meats by lactic acid bacteria, as

described by Niven et al. (1949), consisted of the production of green discolorations and slime. Spoilage under anaerobic condition is usually described by the terms taint, souring and putrefaction. Souring results mainly from the accumulation of organic acids during the bacterial enzymatic degradation of organic compounds. Putrefaction is the anaerobic decomposition of proteins with the production of foul-smelling compounds (Zottola, 1972). Enterococci and Lactobacillus spp. are reported to predominate in vacuum packaged sliced ham (Surkiewicz et al., 1977).

Allen and Foster (1960) investigated the spoilage of vacuum-packaged sliced processed meats during refrigerated storage. Lactic acid bacteria were found predominately in the samples and these bacteria could tolerate high concentrations of salt (6.5 %). Although these bacteria could tolerate high concentrations of salt, a small additional quantity might further inhibit their growth and lengthen the storage life of the products. They also observed that these bacteria caused a typical flavor and slime formation when the count approached 10^8 /g.

Kempton and Bobier (1970) reported that acid-tolerant lactic acid bacteria were only a small component of the initial microflora of vacuum-packed cured meats, however,

these organisms later became prominent during storage at 5 °C. They also stated that bacteria proliferated rapidly in the first two weeks and the maximum stationary phase was attained in 3-4 weeks. A level of about 10^8 organisms per gram was sustained for the duration of the experiments. There was no relationship between bacterial growth and spoilage. Bologna and cooked ham retained their original odor and appearance throughout the entire 15 weeks period.

A low incidence of pathogenic bacteria has been reported for vacuum packaged cooked meat products (Paradis and Stiles, 1978; Surkiewicz et al, 1977). Salmonella has exhibited some resistance to sodium nitrite at the levels currently used in cured meat. However, Salmonella does not grow in vacuum packaged cured meats (Davidson and Webb, 1973).

Vacuum packaging systems have been proposed to extend the shelf-life of various meat products. Vacuum packaging tends to minimize shrink loss, discoloration and retards growth of common aerobic spoilage bacteria. The most significant microbial effect of vacuum packaging is the restriction of growth of aerobic bacteria so that lactic acid bacteria become dominant.

Steele and Stiles (1981) stated that predominant

bacteria in the vacuum-packaged hams were lactic acid bacteria, and pH was not a reliable indicator of microbial load. There was no indication that products with total counts as high as 10^9 and 10^{10} per g were in any way unsafe for human consumption, and no obvious signs of spoilage were apparent in the product with these microbial loads. However, Mol et al. (1971) examined samples obtained from retail outlets and found that products with a total count greater than about 10^8 /g were unacceptable. In contrast, Surkiewicz et al. (1977) found that vacuum-packaged sliced ham remained organoleptically acceptable after 68 days storage at 3 °C, eventhough the count exceeded 10^8 /g after about 48 days.

Egan et al. (1980) found that Microbacterium thermosphactum caused rapid spoilage. Significant aroma changes occured when the bacterial populations reached 10^8 /g and flavor changes 2-3 days later. In contrast Lactobacilli caused spoilage much more slowly. No significant aroma change was detected with products which had carried a population of 10^8 /g for 21 days. Thus shelf-life is dependent upon the types of bacteria present. McBride and Richardson (1981) stated that vacuum-packaged ham could keep well at 5 °C for at least 11 weeks after processing.

Smoking

The smoking of meat is the process of exposing a product to wood smoke (natural or liquid) during its manufacture and results in the development of a specific flavor, aroma and provides a preservative effect.

Foster and Simpson (1961) and Foster et al. (1961) demostrated that smoking is an adsorption or scrubbing process, rather than a settling process. They observed that the rate of deposition of phenols was about 20 times as high for wet surfaces as for dry surfaces.

Husaini and Cooper (1957) concluded that phenolic compounds are of great importance in smoke flavor. Weistreich (1977) stated that the phenolic fraction is the primary source of the smoky aroma and flavor. The phenolic fraction is thought to also be responsible for the preservative properties of wood smoke.

Draudt (1963) reported that smoke helps to preserve meat by acting as an antioxidant and providing a protective film on the surface. Gibbons et al. (1954) demonstrated that smoke constituents (phenols, formaldehyde, cresols etc.) were chiefly responsible for the bacteriocidal effect of the smoking process.

The smoking operation is generally carried out during the early phase of thermal processing. Kemp et al. (1961)

reported that shrinkage tended to increase with higher smoking temperatures, especially above 120°F. Hams smoked below 110°F had a more desirable appearance, color and aroma than those smoked above 110°F. As smoking temperatures increased, the development of peroxides tended to decrease.

Thermal Processing

It is generally agreed that the characteristic odor of a meat can be produced by heating together the isolated odor precursor and the fat fraction. Heating of meat causes certain physical and chemical changes in muscle proteins which affect the quality of cooked meat and meat products.

Laakkonen et al. (1970) theorized that the heat-induced change of fibrous connective tissue to granular connective tissue has a tenderizing effect, whereas the heat denaturation of the myofibrillar proteins has a toughening effect. It is known that temperature changes the solubility of the meat proteins. Sarcoplasmic and myofibrillar proteins are denatured during the heating of meat, the extent of denaturation is dependent on the temperature attained (Hamm, 1966). Hamm and Deatherage (1960) stated that mild denaturation of protein occurs

between 30 - 40 °C followed by considerable protein alteration between 40 - 65 °C. Coagulation of the myofibrillar proteins begins between 30 and 40 °C and is nearly complete at 55 °C.

Rogers et al.(1967) reported that pH values of muscles increased with an increase in endpoint temperature. Kauffman et al. (1964) observed that the pH of pork muscle oven-heated to 77 °C was 0.35 unit higher than that of raw samples. These heat-induced changes in protein solubility are related to changes in the water holding capacity (WHC) of the meat. Bouton and Harris (1972) found that the biggest change in WHC occurred between the raw material at room temperature and the samples cooked at 60 °C.

The binding of meat chunks or particles to form composite products is a heat mediated reaction (Vadehra and Baker, 1970). They also reported that cooking temperature had an important effect on poultry meat binding. Stronger binds were developed when the meat was heated for long periods at low temperature.

Laakkonen et al. (1970) found that the weight loss of various beef muscles was dependent on the final temperature attained during the cooking process. Acton

(1972a) found the percent cooking loss significantly increased as the internal temperature of the chicken loaves increased. However, the binding strength significantly increased as the internal temperature increased in the range 35-82 °C. The maximum strength had had been attained at 82 °C, further heating to an internal temperature of 94 °C caused a significant ($p < .05$) reduction in the binding strength when compared to that observed at 82 °C. The heat-mediated binding reaction began at approxmately 40 °C (Vadehra and Baker 1970). Rogers et al. (1967) indicated that weight losses increased with each increasing increment in endpoint temperature for poultry thigh-legs and breasts. The greatest increase in weight losses occured between 55 and 65 °C for both breasts and thigh-legs. Hale et al. (1977) found cooking to an internal temperature of 76 °C gave better cooked yield than cooking to 79 °C.

Heat processing also functions to stabilize the cured meat pigment by the denaturation of nitroso myoglobin. Fox et al. (1967) stated that cooking at higher temperatures produced a more-rapid rate of color formation than cooking at lower temperature. He also found that appreciable denaturation of the purified pigment did not occur until 160 °F during cooking periods. It may be

assumed that cooking to 160 °F denatures the endogenous reducing enzyme systems, or at least reduces their activity.

Acton (1983) reported that improper temperature difference or humidity during product processing resulted in emulsion breakdown, too rapid internal moisture migration, or case-hardening at the surface from excessive dehydration. Thus, in most processes, there are staged or successive moving air and relative humidity increases at specific time intervals. The advantages of staged processes include (1) more even heating rates for the product's initial temperature to its endpoint temperature; (2) more effective removal of surface moisture occurs initially and a more even rate of moisture migration to the surface occurs during later stages of heating; (3) a more desirable surface skin formation develops as protein denaturation at the product surface begins; (4) slightly greater and more uniform color development is observed and (5) a firmer texture results. The major disadvantage of stage processing in cooking of products is that the percent shrink is 1 - 3% greater than single temperature processes due to longer cooking times. Bayne et al. (1971) and Bramblett and Vail (1964) have suggested that a slower

rate of heat penetration results in increased collagen solubilization without excessive hardening of muscle fibers.

Hearne et al. (1978) stated slower heating and higher endpoint temperatures result in greater cooking losses. An increase in fiber disintegration with heating of cores from 60 to 70 °C suggested an increase in tenderness.

Typical heat processed meat products are cooked until internal temperatures of 65 - 75 °C are attained. This temperature is sufficient to kill most of the microorganisms present and subsequently prolongs product shelf life and improves product safety.

METHODOLOGY

Source of Meat. A total of 182 Kg of fresh pork hams were obtained from a nearby commercial meat packer (John Morrell, Sioux Falls, SD). Frozen boneless, skinned turkey thigh meat was purchased from Dakota Poultry Processors Inc. (Watertown, SD).

Processing Procedures. Pork hams were boned and trimmed of excess fat and connective tissue. In the ham preparation, all external skin, most of the external fat, intermuscular fat and trimmable connective tissue were removed as the hams were boned. The raw meats were cut into chunks averaging 8 to 10 cm in diameter. Five treatments of various combinations of pork and turkey meat were examined in the study and are summarized in table 1.

Table 1. TREATMENTS

	PORK		TURKEY	
	(%)	(Kg)	(%)	(Kg)
TREATMENT 1	100	22.0	0	0.0
TREATMENT 2	75	17.0	25	5.7
TREATMENT 3	50	11.4	50	11.4
TREATMENT 4	25	5.7	75	17.0
TREATMENT 5	0	0.0	100	22.0

The experiment was replicated three times. Each treatment

was manufactured with different combinations of boneless pork ham and turkey thigh meat.

Twenty percent water, 2.25% curing salt and 0.4% sodium tripolyphosphate were added to the product based upon green meat weight. The curing salt ingredient composition consisted of sugar (0.12%), sodium nitrite (not more than 0.75 %), propylene glycol (0.5%) and salt (98.63%). The raw meats were placed in a VORTRON vacuum tumbler (E-Zuber Engineering, Inc., Minneapolis, MN; Model # 250) at 5 ^{o}C and tumbled on an intermittent schedule for 7 hours, which involved 30 minutes of tumbling followed by a 5 minute rest period.

The product was stuffed into fibrous casings to form approximately 2.5-3.5 Kg hams (diameter about 12.5 cm). Each batch of hams were weighed before and after tumbling and after cooking (after chilled 8 hr). Hams were uniformly hung on smokehouse trucks to maximize surface exposure to smoke and heat. The smokehouse, a FESSMANN, TURBOMAT 3000 (U.S. Supplier, T.W. Kutter, Inc., Avon, MA) equipped with a microprocessor was used in this study. Cooking and smoking was performed according to a programmed schedule which is summarized in Table 2.

Hams were removed from the smokehouse and water showered until internal temperature reached 40 ^{o}C (100 ^{o}F)

and held in a 2 °C cooler overnight. Each batch was weighed for yield data. One ham from each batch was randomly chosen and sliced into 2.5 cm pieces. The slices were vacuum packaged in a high barrier film, and stored in cardboard boxes at 2 °C, until analyses.

TABLE 2. THERMAL PROCESSING SCHEDULE

Stage	Time	Smokehouse temperature (C)	Relative humidity (%)	Smoking
1	20 min	50	20	off
2	1.5 hr	55	40	on
3	1.0 hr	60	50	off
4	1.0 hr	65	50	off
5	1.0 hr	70	60	off
6	1.0 hr	75	60	off
7	1.0 hr	80	60	off
8	Until done	85	60	off

LABORATORY ANALYSES

Cooking yield. The cooking yields were determined using the following formula:

$$\% \text{ Cooking Yield} = \frac{\text{Finished Product Wt.}}{\text{Initial Product Wt.}} * 100$$

The added water cooking yields were determined using the following formula:

$$\% \text{ Water Added Yield} = \frac{\text{Finished Product Wt.}}{\text{Raw Meat Wt.}} * 100$$

Cooking loss percentages were determined by subtracting the percent cooking yield from 100 percent.

Proximate Analysis. The moisture, fat, ash and protein composition of the ham was determined in duplicate according to the Association of Offical Chemists (AOAC, 1975) approved methods.

Homogenization of samples was accomplished as follows: samples were frozen to -195 ^{o}C with liquid Nitrogen. Randomly selected samples were shattered by the impact of a hand held hammer. The small meat pieces were then ground in a stainless steel Waring blender, prechilled with liquid nitrogen prior to use. The finely powdered homogenized samples were placed in pre-coded plastic bags and held in a -30 ^{o}C freezer until analysis.

Color Measurement. Ten grams of the minced sample was placed in a beaker first mixed to a smooth paste with approximately 10 ml of a mixture containing 40 ml of acetone and 3 ml of water. The remainder of the acetone solution was then added, and after five minutes with intermittent mixing, the solution was filtered through Whatman filter paper #4. The light absorption of the

filtrate was measured at a wave length of 540 nm using a 1-cm cell, with an 80 % acetone / water solution as a blank. The value so obtained may be used directly as a comparative measure of the pigment concentration (Hornesy, 1956).

Total pigment determination was performed by mixing ten grams sample and a solution containing 40 ml of acetone, 1 ml of concentrated hydrochloric acid and 2 ml of water. After one hour mixing, the solution was filtered through Whatman filter paper #4. The optical density of this filtrate at 640 nm was then a measure of the total heme pigments present in the meat (Hornesy, 1956). The pigment determinations were performed at the end of 1, 3, 6, and 9 weeks storage.

Thiobarbituric Acid (TBA) Analysis. The distillation procedure for the quantitive determination of malonaldehyde in rancid foods, described by Tarladgis et al. (1960), was used. A 10 g sample of meat was blended with 50 ml of distilled water with a Waring blender for 2 minutes. The mixture was then quantitatively transferred into a Kjeldahl flask. Fifty ml of 1.0 N hydrochloric acid was added, using a portion of it to rinse the flask in which the meat was blended. A small amount of Dow antifoam A was put into the lower neck of the flask and a

few boiling beads added to prevent bumping. The mixture in the flask was then distilled at the highest setting of a Kjeldahl apparatus until 50 ml of distillate was collected. The distillate was mixed throughly and 5 ml transferred into a test tube. Five ml of TBA reagent (0.02 M TBA solution in 90% glacial acetic acid) was added to the 5 ml distillate in the test tube. The tube was stoppered, the contents were mixed, then it was immersed in a boiling water bath for 35 minutes. A distilled water-TBA reagent blank was prepared and treated like the samples. After heating, the tubes and contents were cooled in tap water for 10 minutes and portions were transferred into cuvettes and the optical density of the samples read against the blank at 538 nm using a Bausch & Lomb Spectronic 20 spectrophotometer. TBA number refers to the mg of malonaldehyde per 1,000g of sample and it is calculated by multiplying the absorbancy by a constant K (7.8 based upon a standard curve). Malonaldehyde bis (dimethyl acetal) was used as a standard in all TBA tests. TBA analyses were done at 1, 3, 6 and 9 weeks.

pH Test. Ten grams of sliced meat sample was combined with 100 ml distilled water for one minute in a Waring blender jar. The pH was measured on a Corning Model 12 research meter. The pH tests were done at 1, 3, 6 and 9

weeks.

Microbiological analysis. Randomly selected samples were opened aseptically and a section was removed by slicing across the center of the stack of slices with a sterile knife. The sample was adjusted to 25 g by trimming along the edge of the strip and blending for 2 minutes with 225 ml of sterile diluent in a sterile Waring blender jar. Appropriate dilutions were made, transferred to petri dishes, and poured with Standard Plate Count Agar. Plates were incubated aerobically at 32°C for 48 hours and at 5°C for 10 days. Anaerobic plates were incubated in a BBL Gas Pak 150 System (Becton, Dickinson & Co., Cockeysville, MD) at 32°C for 48 hours.

A bacterial count was made on each product during the 1st and at the 3rd, 6th and 9th weeks of the study on samples stored at 2°C. Results from plate count determinations are reported as logarithm of bacterial numbers per gram of tissue. A countable plate for a standard size petri dish is 30 to 300 colonies.

Sensory Evaluation. Responses from 225 untrained consumers were gathered on 1 day approximately 2 to 3 weeks after processing. The taste panels were held during a weekend in the University Mall at Brookings, South Dakota. The three replications of the five treatments (15

batches) were number coded and served to panelists by replicate. Panelists were provided with a pen, cup of water and instructions about the nature of the taste panel. Seventy five responses per replicate were obtained. Panel members evaluated samples for flavor, juiciness and overall acceptability on a seven point hedonic scale with seven representing liked extremely and one being disliked extremely. Rinse water was provided and encouraged to be used to remove any residual after taste between samples.

Statistical Analysis. The main experimental design of this study was a random block design with five treatments and three replications. Analysis of variance, means and standard errors, and orthogonal contrasts test were computed using the Statistical Analysis System (SAS, 1982) to determine differences between treatment means in this study.

Literature Cited

Acton, J.C. 1972a. Effect of heat processing on extractability of salt-soluble protein, tissue binding strength and cooking loss in poultry meat loaves. J. Food Sci. 37:244.

Acton, J.C. 1972b. The effect of meat particle size on extractable protein, cooking loss and binding strength in chicken loaves. J. Food Sci. 37:240.

Acton, J.C. and McCaskill, L.H. 1972. Effect of partial protein removed from muscle cubes in properties of poultry meat loaves. J. Milk Food Technol. 35(10):571.

Acton, J.C. and Saffle, R.L. 1969. Preblend and prerigor meat in sausage emulsions. Food Technol. 23:367.

Acton, J.C. 1983. Smokehouse performance affects yield, quality of further processed turkey. Turkey World. (May- July):17.

Acton, J.C. 1984. Protein-protein interaction in processed meats. In "Proc. 37th Annual Recip. Meat Conf," Amer. Meat Sci. Assoc. Texas Tech. Univ., Lubbock, Tx. p. 36.

Allen, J.R. and Foster, E.M. 1960. Spoilage of vacuum-packaged sliced processed meats during refrigerated storage. Food Res. 25:19.

Allen, C.E. and Foegeding, E.A. 1981. Some characteristics and interactions in muscle foods - A review. Food Technol. 35(5):253.

Anonymous. 1971. New development in ham and meat tumbling. Food Processing Ind. 40(2):472.

Anonymous. 1978. Advantages of vacuum chopping in sausage manufacturing. Meat Industry 24(10):65.

AOAC. 1975. "Official Reference Methods of Analysis." 12ed. Association of Offical Analytical Chemists, Washington, DC.

Babji, A.S., Froning, G.W. and Ngoka, D.A. 1982. The effect of short-term tumbling and salting on the quality on turkey breast muscle. Poultry Sci. 61:300.

Bard, J.C. 1965. Some factors influencing extractibility of salt-souble proteins. In "Proc. Meat Industry Research Conference." American Meat Institute Foundation, Chicago, IL. p. 96.

Bard, J. and Townsend, W.E. 1971. Cured Meats, In "The Science of Meat and Meat Products." Ed. by Price, J.F. and Schweigert, B.S., W. H. Freeman and Co. San Francisco, p. 452.

Bayne, B.H., Strawn, S.S., Hutton, C.W., Backus, W.R. and Meyer, B.H. 1971. Relationship of alkali and ringer insoluble collagen to tenderness of beef heated at two rates. J. Anim. Sci. 33:958.

Bodwell, C.E. and McClain, P.E. 1971. Chemistry of Animal Tissue. In "The Science of Meat and Meat Products." Ed. by Price, J.F. and Schweight, B.S., W.H. Freeman and Co., San Francisco, p. 78.

Bouton, P.E. and Harris, P.V. 1972. The effects of cooking temperature and time on some mechanical properties of meat. J. Food Sci. 37:140.

Brahms, J. and Brezner, J. 1961. Interaction of myosin A with ions. Arch Biochem. Biophys. 95:219.

Bramblett, V.D. and Vail, G.R. 1964. Further studies on the qualities of beef as affected by cooking at very low temperature for long periods. Food Technol. 18:245.

Burke, M., Himmelfarb, S., and Harrington, W.F. 1973. Studies on the "Hinge" region of myosin. Biochem. 12(4):701.

Bushway, A.A., Ficker, N. and Jen, C.W. 1982. Effect of nitrite and sorbate on total number of aerobic microorganisms in chicken white and dark patties. J. Food Sci. 47:858.

Cassidy, R. D. 1977. Histological investigation of the effects of tumbling method, phosphate content, and internal cooked temperature on porcine muscle tissue. MS. Thesis. The Ohio State University, Columbus, Ohio.

Cassidy, R. D., Ockerman, H.W., Krol, B., Van Roon, P.S., Plimpton, R.F. Jr. and Cahill, V.R. 1978. Effect of tumbling method, phosphate level and final cook temperature on histological characteristic of tumbled porcine muscle tissue. J. Food Sci. 43:1514.

Castellani, A.G. and Niven, C.F.Jr., 1955. Factors affecting the bacteriostatic action of sodium nitrite. Appl. Microbiol. 3:154.

Chen, T.C. and Waimalenogoraek, C. 1981. Effect of pH on TBA value of ground raw poultry meat. J. Food Sci. 46:1946.

Chesney, M.S., Mandigo, R.W. and Cambell, J.F. 1978. Properties of restructured pork product as influenced by meat particle size, temperature and comminution method. J. Food Sci. 43:1535.

Cho, I.C. and Bratzler, L.J. 1970. Effect of sodium nitrite on flavor of cured pork. J. Food Sci. 35:668.

Cross, C.K. and Ziegler, P. 1965. Comparison of the volatile fraction from cured and uncured meat. J. Food Sci. 30:610.

Davidson, C.M. and Webb, G. 1973. The behavior of salmonella in vacuum-packaged cooked cured meat products. Can. Inst. Food Sci. Technol. J. 6:41.

DeRobertis, E.D.P. and DeRobertis, E.M.F. 1980. Cell and Molecular Biology. 7th Ed. Sunders College, Philadelphia, chapt. 27, p.585.

Draudt, H.N. 1963. The meat smoking process: A review. Food Technol. 17(12):85.

Durland, P.R., Seideman, S.C., Costello, W.J. and Quenzer, N.M. 1982. Physical and sensory properties of restructured beef steaks formulated with various flake size and mixing time. J. Food Prot. 45:127.

Egan, A.F., Ford, A.L. and Shay, B.J. 1980. A comparison of Microbacterium thermosphactum and Lactobacilli as spoilage organisms of vacuum-packaged sliced luncheon meats. J. Food Sci. 45:1745.

Fapojuwo, O.O. 1981. The composition and stability of lipids in meat products and a spectrofluorometric assay for malonaldehyde. Ph.D. dissertation, Iowa State Univ., Ames, Iowa.

Ferry, J.D. 1948. Protein gels. Adv. Protein Chem. 3:1.

Foster, W.W. and Simpson T.H. 1961. Studies on the smoking process for food. 1. The importance of vapours. J. Sci. Food Agr. 12:363.

Foster, W.W., Simpson, T.H., and Campbell, D. 1961. Studies on the smoking process for food. 2. The role of smoke particles. J. Sci. Food Agr. 12:635.

Fox, J.B., Jr. 1966. The chemistry of meat pigments. J. Agric. Food Chem. 14:207.

Fox, J.B., Jr., Townsend, W.E., Ackerman, S.A. and Swift, C.E. 1967. Cured color development during frankfurter processing. Food Technol. 21:386.

Fukazawa, T., Hashimoto, Y., and Yasui, T. 1961a. Effect of some proteins on the binding quality of an experimental sausage. J. Food Sci. 26:541.

Fukazawa, T., Hashimoto, Y., and Yasui, T. 1961b. The relationship between the components of myofibrillar protein and the effect of various phosphates that influence the binding quality of sausage. J. Food Sci. 26:550.

Galluzzo, S.J. and Regenstein, J.M. 1978. Role of chicken breast muscle proteins in meat emulsion formation: myosin, actin and synthetic actomyosin. J. Food Sci. 43:1761.

Gibbons, N.E., Rose, D. and Hopkins, J.W. 1954. Bactericidal and drying effects of smoking in bacon. Food Technol. 8:155.

Giddings, G.G. 1977. The basis of color in muscle foods. J. Food Sci. 42:288.

Gillett, T.A., Cassidy, R.D. and Simon, S. 1981. Effect of continuous massaging on bind, yield and color of hams. J. Food Sci. 46:1681.

Hadden, J.P., Ockerman, H.W., Cahill, V.R., Parrett, N.A., and Borton, R.J. 1975. Influence of sodium nitrite on the chemical and organoleptic properties of comminuted pork. J. Food Sci. 40:626.

Hale, K.K. Jr., Cohn, D.D. and Stubblefield, J.D. 1977. Effect of finishing diet and cure procedures on quality of smoked poultry. Poultry Sci. 56:211.

Hamm, R. and Deatherage, F.E. 1960. Changes in hydration solubility and charges of muscle proteins during heating of meat. Food Res. 25:589.

Hamm, R. 1966. Heating of muscle systems. In "The Physiology and Biochemistry of Muscle as Food," Ed. by E.J. Trautman, Univ. of Wisconsin Press, Madison, p. 363.

Hamm, R. 1970. Interactions between phosphates and meat proteins. In Symposium: "Phosphates in Food Processing." Ed. by Deman, J.M. and Melnycnyh, P., AVI Publishing Co. Connecticut, Westport, p. 65.

Hasiak, R.J., Chaves, J., Sebranek, J. and Kraft, A.A. 1984. Effect of sodium nitrite and sodium erythorbate on the chemical, sensory and microbiological properties of water-added turkey ham. Poultry Sci. 63:1364.

Hearne, L.E., Penfield, M.P. and Geortz, G.E. 1978. Heating effects on bovine semitendinosus: Shear, muscle fiber measurements, and cooking losses. J. Food Sci. 43:10.

Hermansson, A.M. 1978. Physico-chemical aspects of soy proteins structure formation. J. Texture Studies. 9:33.

Hornsey, H.C. 1956. The colour of cooked cured pork. 1. Estimation of nitric oxide-heam pigments. J. Sci. Food Agric. 7:534.

Husaini, S.A. and Cooper, G.E. 1957. Fractionation of wood smoke and the comparison of chemical composition of sawdust and friction smokes. Food Technol. 11:499.

Kauffman, R.G., Carpenter, Z.L., Bray, R.W. and Hoekstra, W.G. 1964. Biochemical properties of pork and their relationship to quality. 1. pH of chilled, aged, and cooked muscle tissue. J. Food Sci. 29:65.

Kawakami, H., Morita, J., Takahashi, K. and Yasui, T. 1971. Thermal denaturation of myosin, heavy meromyosin and subfragment. J. Biochem. 70:635.

Kemp, J.D., Moody, W.G. and Goodlett, J.L. 1961. The effects of smoking and smoking temperatures on the shrinkage, rancidity development, quality and palatability of dry-cured hams. Food Technol. 15:267.

Kempton, A.G. and Bobier, S.R. 1970. Bacterial growth in refrigerated, vacuum-packed luncheon meat. Can. J. Microbiol. 16:287.

Knipe, C.L. 1982. Sectioned and formed meat products. In Proceedings of the Fourth Annual Sausage and Processed Meats Short Course, Iowa State University.

Knipe, C. L., Plimpton, R.F. and Ockerman, H.W. 1981. Effect of tumbling and tumbling temperature on total aerobic plate counts (incubated at 25 C) and quality of boneless, cured hams. J. Food Sci. 46:212.

Kotter, L. and Fischer, A. 1975. The influence of phosphates or polyphosphates on the stability of foams and emulsions in meat technology. Die Fleischwirstains. Nv. 3:365.

Krause, R.J., Ockerman, H.W., Krol, B., Moerman, P.C. and R.F. Plimpton Jr. 1978a. Influence of tumbling, tumbling tim and sodium tripolyphosphate on quality and yield of cured hams. J. Food Sci. 43:853.

Krause, R.J., Plimpton, R.F., Ockerman, H.W. and Cahill, V.R. 1978b. Influence of tumbling and sodium tripolyphosphate on salt and nitrite distribution in porcine muscle. J. Food Sci. 43:190.

Laakkonen, E., Wellington, G.H. and Sherbon, J.W. 1970. Low-temperature, long-time heating of bovine muscle. 1. Changes in tenderness, water-binding capacity, pH and amount of water soluble components. J. Food Sci. 35:175.

Lechowich, R.V. 1971. Microbiology of Meat. In "The Science of Meat and Meat Products." Ed. by Price, J.F. and Schweigert. B.S., W.H. Freeman and Co., San Francisco, p. 230.

Lehninger, A.L. 1982. Principles of Biochemistry. Worth Publishers, Inc., New York, p. 163.

Lin, H.S., Sebranek, J.G., Galloway, D.E. and Lind, K.D. 1980. Effect of sodium erythorbate and packaging conditions on color stability of sliced bologna. J. Food Sci. 45:115.

Liu, H. and Watts, B.W. 1970. Catalysts of lipid oxidation in meats. 3. Catalysis of oxidative rancidity in meats. J. Food Sci. 35:596.

Macfarlane, J.J. and McKenzie, I.J. 1976. Pressure-induced solubilization of myofibrillar proteins. J. Food Sci. 41:1442.

Macfarlane, J.J., Schmidt, G.R. and Turner, R.H. 1977. Binding of meat pieces: A comparision of myosin, actomyosin and sarcoplasmic proteins as binding agents. J. Food Sci. 42:1603.

Maesso, E.R., Baker, R.C., Bourne, M.C., and Vadehra, D.V. 1970. Effect of some physical and chemical treatments on binding quality of poultry loaves. J. Food Sci. 35:440.

Mandigo, R.W., Hansen. K.R. and Chesney, M.S. 1973. Effect of salt content and flaking temperature on flaked, formed and sectioned meat products. J. Anim. Sci. 37:269.

Mandigo, R.W. 1982. Processing system-mixing, temperature control and raw materials. In "Proc. Int. Symp. Meat Sci. and Technol." National Livestock and Meat Board. Chicago, IL. p. 24.

Mahon, J.H. 1961. Tripolyphosphate-salt synergism and its effect on cured meat volume. Proc. of the 13th Res. Conf. Amer. Meat Sci. Assoc. and Amer. Meat Ind. Foundation. Chicago, IL. p. 34.

Maurer, A.J., Baker, R.C. and Vadehra, D.V. 1969. Kind and concentration of soluble protein extract in the emulsifying capacity of poultry meat. Food Technol. 23(4):177.

McBride, R.L. and Richardson, K.C. 1981. Acceptability of chilled and frozen ham. CSIRO Food Research Quarterly 41(2):44.

Mills, E.W., Plimpton, R.F. and Ockerman, H.W. 1980. Residual nitrite and total microbial plate counts of hams as influenced by tumbling and four ingoing nitrite levels. J. Food Sci. 45:1297.

Moerck, K.E. and Ball, H.R. Jr. 1974. Lipid autoxidation in mechanically deboned chicken meat. J. Food Sci. 39:876.

Mol, J.H.H., Hietbrink, J.E.A., Mollen, H.W.M. and Van, T.J. 1971. Observations on the microflora of vacuum packed sliced cooked meat products. J. Appl. Bacteriol. 34:377.

Nakayama, T. and Sato, Y. 1971a. Relationships between binding quality of meat and myofibrillar proteins. Agr. Biol. Chem. 35(2):208.

Nakayama, T. and Sato, Y. 1971b. Relationships between binding quality of meat and myofibrillar proteins. 3. Contribution of myosin A and actin to rheological properties of heated minced-meat gel. J. Text. Studies 2:75.

Neer, K.L. and Mandigo, R.W. 1974. Effect of tripolyphosphates and salt on flaked, cured pork. J. Anim. Sci. 39:73.

Niven, C.F. Jr., Castellani, A.G. and Allanson V. 1949. A study of the lactic acid bacteria that cause surface discoloration of sausages. J. Bacterial 38:633.

Ockerman, H. W. and Organisciak, C. S. 1978. Diffusion of curing brine in tumbled pork tissue. J. Food Prot. 41:178.

Ockerman, H. W., Cahill, R.F. and Parrett, N.A. 1978. Influence of short term tumbling, salt and phosphate on cured canned pork. J. Food Sci. 43:878.

Ockerman, H,W. and Kwiatek, K. 1984. Effect of tumbling and tumbling temperature on surface and subsurface contamination of Lactobacillus Plantarum and residual nitrite in cured pork shoulder. J. Food Sci. 49:1634.

Paradis, D.C. and Stiles, M.E. 1978. A study of microbial quality of vacuum packaged, sliced bologna. J. Food Prot. 41:811.

Rahelic, S., Rede, R. and Jovicic, U. 1966. Effect of polyphosphates on some physicochemical properties of cured pork. Technol. Mesa 7(9): 252.

Rahelic, S., Pribis, V. and Vicevic, Z. 1974. Influence of mechanical treatment of cured muscles on some characteristics of pasterized canned pork. Proc. of the 20th European Meat Res. Workers, p. 133.

Reynolds, J.B., Anderson, D.B., Schmidt, G.R., Theno, D.M. and Siegel, D.G. 1978. The effect of ultrasonic treatment on binding strength in cured ham rolls. J. Food Sci. 43:866.

Rogers, P.J., Goertz, G.E. and Harrison, D.L. 1967. Heat induced changes of moisture in turkey muscles. J. Food Sci. 32:298.

Romans, J.R., Jones, K.W., Costello, W.J., Carlson, W.C. and Ziegler, P.T. 1985. The Meat We Eat, 12 th ed. The Interstate Printers and Publishers, Inc. Danville, IL.

Saffle, R.L., and Galbreath, J.W. 1964. Quantitative determination of salt-soluble protein in various types of meats. Food Technol. 18:1943.

Samejima, K., Hashimoto, Y., Yasui, T., and Fukazawa, T. 1969. Heat gelling properties of myosin, actin, actomyosin and myosin-subunits in a saline system. J. Food Sci. 34:242.

Samejima, K., Takahashi, K., and Yasui, T. 1976. Heat-induced denaturation of myosin total rod. Agric. Biol. Chem. 40(12):2455.

Samejima, K., Ishioroshi, M., and Yasui, T. 1981. Relative roles of the head and tail portions of the molecule in the heat-induced gelation of myosin. J. Food Sci. 46:1412.

SAS Institute Inc. 1982. SAS User's Guide Statistics, 1982 ed. SAS Institute Inc., Cary, NC.

Sato, K. and Hegarty, G.R. 1971. Warmed-over flavor in cooked meats. J. Food Sci. 36:1098.

Schmidt, G.R. 1977. Why massage or tumble? Meat Industry 11:40.

Schmidt, G.R. and Siegel, D.G. 1978. Sectioned and formed meat. Proc. 31st Reciprocal Meat Conference. Amer. Meat Sci. Assoc. and Amer. Meat Ind. Foundation. Chicago, IL. p. 18.

Schmidt, G.R. and Trout, G.R. 1982. Chemistry of Meat Binding. Proc. Int. Symp. Meat Sci. and Technol., National Live Stock and Meat Board. Chicago, IL. p. 265.

Schnell, P.G., Vadehra, P.V. and Baker, R.C. 1970. Mechanism of binding chunks of meat. 1. Effect of physical and chemical treatments. Can. Inst. Food Tech. J. 3(2):44.

Schut, J. 1976. Meat Emulsion. In "Food Emulsions." Ed. by Friberg, S. Marcel, Dekker, Inc., NY.

Sczesniak, A.S. and Torgeson, K.W. 1965. Methods of meat texture measurement viewed from the background of factors affecting tenderness. Adv. Food Res. 14:33.

Sebranek, J.G., 1980. Nitrates, nitrites and the chemistry of meat color. In "Proc. 2nd Annu. Sausage Processed Meats Short Course." Ames, IA. 2:8.

Shults, G.W. and Wierbicki, E. 1973. Effect of sodium chloride and condensed phosphates on water holding capacity, pH and swelling of chicken muscle. J. Food Sci. 38:991.

Siegel, D.G. and Schmidt, G.R. 1979. Ionic, pH, and temperature effect on the binding ability of myosin. J. Food Sci. 44:1686.

Siegel, D.G. and Theno, D.M., Schmidt, G.R. and Norton, W.H. 1978a. Meat Massaging: the effect of salt, phosphate and massaging on cooking loss, binding strength and exudate composition in sectioned and formed ham. J. Food Sci. 43:331.

Siegel, D.G., Theno, D.M. and Schmidt, G.R. 1978b. Meat massaging: The effect of salt, phosphate and massaging on the presence of special skeletal muscle protein in the exudate of a sectioned and formed ham. J. Food Sci. 43:327.

Solomon, L.W. and Schmidt, G.R. 1980. The effect of vacuum and mixing time on the extractability and functionality of pre- and postrigor beef. J. Food Sci. 45:283.

Steele, T.E. and Stiles, M.E. 1981. Microbial quality of vacuum packaged sliced ham. J. Food Prot. 44(6):435.

Surkiewicz, B.F., Harris, M.E. and Carosella, J.M. 1977. Bacteriological survey and refrigerated storage test of vacuum-packaged sliced imported canned ham. J. Food Prot. 40:109.

Szent-Gyorgyi, A.G. 1952. Proceedings Fourth Research Conference, American Meat Institute, p. 22.

Tarladgis, B.G., Watts, B.M., Younathan, M.T. and Dugan, L. Jr. 1960. A distillation method for quantitative determination of malonaldehyde in rancid foods. J. Amer. Oil Chem. Soc. 37:44.

Theno, D.M. 1977. The microstructure of sectioned and formed meat products. Ph.D. Disseration. The Univ. of Illinois at Urbana, Champaign.

Theno, D.M., Siegel, D.G. and Schmidt, G.R. 1978a. Meat massaging: Effects of salt and phosphate on the microstructural composition of the muscle exudate. J. Food Sci. 43:483.

Theno, D.M., Siegel, D.G. and Schmidt, G.R. 1978b. Meat massaging: Effects of salt and phosphate on the ultrastructure of cured porcine muscle. J. Food Sci. 43:488.

Theno, D.M., Siegel, D.G. and Schmidt, G.R. 1978c. Meat massaging: Effects of salt and phosphate on the microstructure of binding junctions in sectioned and formed hams. J. Food Sci. 43:493.

Thomson, J.E. 1964. Effect of polyphosphates on oxidation deterioration of commercially cooked fryer chickens. Food Technol. 18:1085.

Tims, M.J. and Watts, B.M. 1958. Protection of cooked meat with phosphates. Food Technol. 12:240.

Turner, R.H., Jones, P.N., and Macfarlane, J.J. 1979. Binding of meat pieces: An investigation of the use of myosin-containing extracts from pre- and post-rigor bovine muscle as meat binding agents. J. Food Sci. 44:1443.

USDA, 1984. Livestock and Poultry Outlook and Situation Report. December, 1984.

Vadehra, D.V. and Baker, R.C. 1970. The mechanism of heat initiated binding of poultry meat. Food Technol. 24(7):42.

Vadehra, D.V., Schnell, P.G. and Baker, R.C. 1970. Effect of enzymes, muscle proteins and temperature on the binding ability of poultry meat. Poultry Sci. 49:1447 (Abstract).

Vartorella, T.R. 1975. The effect of tumbling, salt and TPP on selected quality characteristics of cured, canned pork. MS. Thesis. The Ohio State University, Columbus, Ohio.

Weiss, G.M. 1973. Ham tumbling and massaging. Western Meat Industry 14:23.

Wiestreich, H.E. 1977. Smoking of Meats. In "Proceedings Meat Industry Research Conference. Chicago, IL. p. 37.

Wierbicki, E., Howkes, J.J. and Shults, G.W. 1976. Effect of salt, phosphates and other curing ingredients on shrinkage of lean pork meat and the quality of smoked processed ham. J. Food Sci. 41:1116.

Wilson, N.R.P. 1981. Meat and Meat Products. Appl. Sci. Publishers, New Jersey.

Yasui, T., Morita, J. and Takahashi, K. 1966. Inhibition by some neutral organic solutes of the denaturation of myosin A-adenosine triphosphatase. J. Biochem. 60:303.

Yasui, T., Ishioroshi, M., Nakano, H. and Samejima, K. 1979. Changes in shear modulus, ultrastructure and spin-spin relaxation times of water associated with the heat-induced gelation of myosin. J. Food Sci. 44:1201.

Younathan, M.T. and Watts, B.M. 1959. Relationship of meat pigments to lipid oxidation. Food Res. 24:728.

Zabillaga, M.P., Maerker G. and Foglia T. A. 1984. Antioxidant activity of sodium nitrite in meat. J. Amer. Oil Chem. Soc. 61(4):772.

Zisper, M.W., Kwon, T.W., and Watts, B.M. 1964. Oxidative changes in cured and uncured frozen cooked pork. J. Agr. Food Chem. 12:105.

Zottola, E.A. 1972. Introduction to Meat Microbiology. Amer. Meat Inst., Chicago, IL. p. 34.

CHEMICAL AND SENSORY PROPERTIES OF WATER-ADDED HAM BLENDS CONTAINING PORK AND TURKEY THIGH MEAT

C.M. CHEN AND K.W. JONES

SOUTH DAKOTA STATE UNIVERSITY, BROOKINGS.

ABSTRACT

Five treatments contained the following ratios of pork and turkey meat: 1) 100:0; 2) 75:25; 3) 50:50; 4) 25:75; 5) 0:100. Product was vacuum tumbled, smoked and cooked to an internal product temperature of 72°C. No major differences were observed in smokehouse yields between treatments; however, minor differences were found in "water added" cooking yields. Product containing 50% or more turkey meat was lower ($P < 0.05$) in fat content than treatments containing predominantly pork. Total pigment and nitroso pigment values increased ($P < 0.05$) as the level of turkey meat increased in the formulation. The presence of turkey thigh meat resulted in significantly higher ($P < 0.01$) pH and TBA values. Consumer sensory panelists found no significant preferential differences between treatments.

Introduction

The production of sectioned and formed ham products made by massaging or tumbling meat chunks into a hemogeous meat mass has become popular with the meat industry and consumers in recent years (Schmidt, 1977; Krause et al., 1978 and Siegel et al., 1978). This technology has become widely practiced in the red meat and poultry industries. This is probably due to the expansion of sectioned and formed technology for both fresh and cured products.

High raw material price volatility of red meats is one of the most important factors influencing the finished product prices. In addition to the price changes, the increasing real disposable personal income and reducing meat supplies should strengthen most meat prices from 1984 to 1985 (USDA, 1984). However, consumer pressure may force the industry to re-examine its products with regard to quality, nutrition and value or to design new products at a lower cost. In response to these changes the meat industry must attempt to provide consumers with a quality product at a lower relative cost in order to meet the changing market demands.

Several reports have stated that turkey ham is similar in quality and lower in price than pork ham (Anonymous,

1976; Acton et al. 1979; Baker and Darfler, 1981 and Hasiak et al., 1984). As a result, U.S. consumption trends have been gradually changing from red meat to poultry meat.

The partial replacement of red meats with poultry meats in processed meat products can be a method to partially eliminate the price fluctuations and provide an economical, high quality product.

The objectives of this study are to examine the chemical, and sensory properties of ham containing various blends of pork and turkey thigh meat.

Materials and Methods

Source of Meat. Two hundred kilograms of fresh pork hams were obtained from a nearby commercial meat packer (John Morrell, Sioux Falls, SD). A similar quantity frozen boneless, skinned turkey thigh meat was purchased from Dakota Poultry Processors Inc. (Watertown, SD).

Processing Procedures. Pork hams were boned and trimmed of excess fat and connective tissue. In the ham preparation, all external skin, most of the external fat, intermuscular fat and trimmable connective tissue were removed as the hams were boned. The raw meats were cut into chunks averaging 8 to 10 cm in diameter. Five treatments of various combinations of pork and turkey meat were examined in the study and are summarized in table 1.

The experiment was replicated three times. Each treatment was manufactured with different combinations of boneless pork ham and turkey thigh meat. Twenty percent water, 2.25% curing salt and 0.4% sodium tripolyphosphate were added to the product based upon green meat weight. The curing salt ingredient composition consisted of sugar (0.12%), sodium nitrite (not more than 0.75%), propylene glycol (0.5%) and salt (98.63%). The raw meats were placed

in a VORTRON vacuum tumbler (E-Zuber Engineering, Inc., Minneapolis, MN; Model # 250) at 5 °C and tumbled on an intermittent schedule for 7 hours, which involved 30 minutes of tumbling followed by a 5 minute rest period.

The product was stuffed into fibrous casings to form approximately 2.5 -3.5 Kg hams (diameter about 12.5 cm). Each batch of hams were weighed before and after tumbling and after cooking (following 8 hr chill). Hams were uniformly hung on smokehouse trucks to maximize surface exposure to smoke and heat. The smokehouse, a FESSMANN, TURBOMAT 3000 (U.S. Supplier, T.W. Kutter, Inc., Avon, MA) equipped with a microprocessor was used in this study. Cooking and smoking was performed according to a programmed schedule which is summarized in Table 2.

Hams were removed from the smokehouse and water showered until internal temperature reached 40 °C (100 °F) and held in a 5 °C cooler overnight. Each batch was weighed for yield data.

Cooking yield. The cooking yields were determined using finished product weight divided by initial products weight. Cooking loss percentage was determined by substracting the percent cooking yield from 100 percent. Finished product weight divided by raw meat weight was the

water added cooking yield.

LABORATORY ANALYSES

Proximate Analysis. The moisture, fat, ash and protein composition of the ham was determined in duplicate according to the Association of Offical Chemists (AOAC, 1980) approved methods.

Color Measurement. Quantification of nitrosopigment was performed by acetone-water extraction according to techniques described by Hornsey (1956). The light absorption of the filtrate (extracted by 40 ml acetone + 3 ml water solution) was measured at a wave length of 540 nm using a 1-cm cell, with an 80 % acetone / water solution as a blank. The value so obtained may be used directly as a comparitive measure of the pigment concentration. The total pigment was measured by the optical density of filtrate (extracted by 40 ml acetone + 1 ml concentrated hydrochloric acid + 2 ml water) at 640 nm.

pH Measurement. Ten gm of sliced meat sample was combined with 100 ml distilled water for one minute in a Waring blender jar. The pH was measured on a Corning Model 12 research meter.

Thiobarbituric Acid (TBA) Analysis. The distillation procedure for the quantitative determination of

malonaldehyde in rancid foods, described by Tarladgis et al. (1960), was used.

Sensory Evaluation. Responses from 225 untrained consumers were gathered on 1 day approximately 2 to 3 weeks after processing. The taste panels were held during a weekend in the University Mall at Brookings, South Dakota. The three replications of the five treatments (15 batches) were number coded and served to panelists by replicate. Panelists were provided with a pen, cup of water and instructions about the nature of the taste panel. Seventy five responses per replicate were obtained. Panel members evaluated samples for flavor, juiciness and overall acceptability on a seven point hedonic scale with seven representing liked extremely and one being disliked extremely. Rinse water was provided and encouraged to be used to remove any residual after taste between samples.

Statistical Analysis. The main experimental design of this study was a random block design with five treatments and three replications. Analysis of variance, means and standard errors, and orthogonal contrast tests were computed using the Statistical Analysis System (SAS, 1982) to determine differences between treatment means in this study.

RESULTS & DISCUSSION

Cooking Yield

Smokehouse yields and water added cooking yields are shown in Table 3. There was no significant difference among the treatments means for smokehouse yields. Significant differences ($P < .05$) were observed among treatments for water added yields. The data indicated that treatment 2 had lower value than the rest of treatments. These differences were probably caused by greater moisture evaporation that occurred because of delays in processing a portion of the replications caused by mechanical failure. However, the data analysis results showed there were no significant differences among pork ham (treatment 1), turkey ham (treatment 5) and treatment 3 (50:50) in water added cooking yield.

Proximate Analyses.

Results of chemical composition of water-added hams are presented in Table 4. The data indicated lower ($P < .05$) moisture content and higher ($P < .05$) protein and fat content was observed in the high level of pork blended treatments. A significantly higher moisture content and lower fat content of higher percentage turkey

treatments were to be expected. The data from Consumer Nutrition Division and Consumer and Food Economics Institute (USDA, 1979, 1983) in comparison of turkey thigh meat and pork ham (raw) indicated higher moisture content and lower fat content are inherent to turkey thigh meat compared to lean pork ham.

Color

The results of total pigment and nitroso pigments are presented in Table 5. Treatment 5 (turkey ham) was significantly ($P < .01$) higher than the rest of treatments and showed a dark pink color. This is due to the higher myoglobin content in turkey thigh meat (Baker and Darfler, 1981). The same trend was observed in the total pigment content between treatments. There was no significant difference between treatment 3 and 4.

pH & TBA Values

Table 5 shows the effects of increasing turkey meat levels on pH and TBA values in water-added hams. The results of the pH data indicated that pork hams had a pH value lower ($P < .01$) than all other treatments. No significant difference was observed between treatments 2 and 3 and between treatments 4 and 5. Generally, the pH value of hams increased as levels of turkey meat

increased. These results are expected since turkey dark meat is known to generally have a higher pH than pork muscle. Higher ($p < .01$) TBA mean values of TBA number were observed in treatment 3, 4 and 5 when measured within 2 days of processing. This result is in agreement with previous literature in that higher unsaturated fatty acids in turkey meat are responsible for higher TBA values.

Sensory Evaluation

Treatment mean values and standard errors for consumer sensory panel preference characteristics are presented in Table 6. Pooled responses indicated that the panel members did not significantly prefer any treatments for all sensory attributes measured.

The treatment 3 blend (50:50) was given slightly higher flavor, juiciness and overall preference by panelists when compared to all other treatments. Although these differences observed in sensory panel preferences were not profound.

CONCLUSIONS

The results of this study indicate that there were no significant differences in smokehouse yields among pork

ham, turkey ham and blend combinations. Pork ham had higher protein, ash and fat contents than turkey ham and blend hams. Turkey ham possessed a darker pink color on account of a higher nitroso pigment content. Generally, the pH value of treatments increased as levels of turkey meat increased. Increasing levels of turkey meat, resulted in slightly elevated, but still highly acceptable TBA values of finished product. No difference was detected in panelist scores between turkey ham, pork ham and pork and turkey blends. This study did not find any significant disadvantage in sensory flavor, juiciness and overall acceptability scores. From an economical standpoint, it would appear that turkey thigh meat can be incorporated into pork ham formulations without a loss in consumer preference. These results indicate that sectioned and formed hhams, acceptable in flavor, juiciness and overall acceptability, can be substituting different levels of pork and turkey blends.

TABLE 1. HAM FORMULATIONS (Kg)

Ingredients (Pork:Turkey)	Trt 1 100:0	Trt 2 75:25	Trt 3 50:50	Trt 4 25:75	Trt 5 0:100
Boneless pork ham	22.7	17.0	11.4	5.7	0.0
Turkey thigh meat	0.0	5.7	11.4	17.0	22.7
Water	4.4	4.4	4.4	4.4	4.4
Curing ingredient	0.56	0.56	0.56	0.56	0.56
Sodium tripolyphosphate	0.10	0.10	0.10	0.10	0.10

TABLE 2. THERMAL PROCESSING SCHEDULE

Stage	Time	Smokehouse temperature (C)	Relative humidity (%)	Smoking
1	20 min	50	20	off
2	1.5 hr	55	40	on
3	1.0 hr	60	50	off
4	1.0 hr	65	50	off
5	1.0 hr	70	60	off
6	1.0 hr	75	60	off
7	1.0 hr	80	60	off
8	Until done (*)	85	60	off

* Until an internal product temperature of 72 ^{o}C was attained.

TABLE 3. EFFECTS OF HAM SAMPLES ON COOKING YIELD, WATER ADDED COOKING YIELD AND COOKING LOSS VALUES.

	Treatments (Ratio Pork : Turkey Meat)					
	Trt 1 (100:0)	Trt 2 (75:25)	Trt 3 (50:50)	Trt 4 (25:75)	Trt 5 (0:100)	S.E.
Cooking yield[a] (%)	87.17	83.58	86.49	86.46	85.01	0.97
Water added cooking yield[b] (%)	105.81 d	101.62 c	104.22 d	105.27 d	103.14 cd	0.72

a. $$\text{Cooking yield (\%)} = \frac{\text{Finished product weight}}{\text{Initial product weight}} * 100$$

b. $$\text{Water added cooking yield (\%)} = \frac{\text{Finished product weight}}{\text{Raw meat weight}} * 100$$

cd. Means in the same raw with a different superscript are significantly different ($P < .05$).

TABLE 4. EFFECTS OF TURKEY MEAT LEVELS ON CHEMICAL COMPOSITION OF WATER-ADDED HAMS.

Treatments (Pork : Turkey)	Moisture (%)	Fat (%)	Protein (%)	Ash (%)
Trt 1 (100:0)	72.11^{a}	5.26^{c}	19.93^{c}	3.09^{b}
Trt 2 (75:25)	72.30^{a}	5.00^{c}	20.08^{c}	3.62^{c}
Trt 3 (50:50)	74.09^{b}	4.40^{b}	19.12^{ab}	3.15^{b}
Trt 4 (25:75)	72.47^{a}	4.54^{b}	19.45^{b}	3.17^{b}
Trt 5 (0:100)	75.21^{c}	3.33^{a}	18.86^{a}	2.81^{a}
S.E.	0.17	0.13	0.12	0.07

a,b,c. Means in same column with a different superscript are significantly different ($p < .05$).

TABLE 5. EFFECTS OF TURKEY MEAT LEVELS ON MEANS OF TOTAL PIGMENT, NITROSO PIGMENT, pH AND TBA VALUES IN WATER-ADDED HAMS.

	Treatments (Ratio Pork : Turkey Meat)					
	Trt 1 (100:0)	Trt 2 (75:25)	Trt 3 (50:50)	Trt 4 (25:75)	Trt 5 (0:100)	S.E.
Total Pigment (ppm)	111.32[a]	110.30[a]	136.94[b]	130.03[b]	145.49[c]	6.74
Nitroso Pigment (ppm)	46.82[a]	47.77[a]	51.96[a]	50.75[a]	75.83[b]	3.29
pH	6.13[a]	6.30[b]	6.33[b]	6.50[c]	6.50[c]	0.03
TBA Value[d]	0.19[a]	0.24[ab]	0.31[b]	0.31[b]	0.30[b]	0.01

a,b,c. Means in the same raw with a different superscript are significantly different ($P < .01$).

d. TBA values = mg malondehyde / 1000 g meat.

TABLE 6. EFFECTS OF SUBSTITUTED TURKEY MEAT ON MEAN VALUES FOR SENSORY EVALUATION OF WATER-ADDED HAMS.[a]

	Treatments (Ratio Pork : Turkey Meat)					
	Trt 1 (100:0)	Trt 2 (75:25)	Trt 3 (50:50)	Trt 4 (25:75)	Trt 5 (0:100)	S.E.
Flavor[b]	5.32	4.85	5.58	5.04	5.08	0.091
Juicy[b]	5.20	5.06	5.57	4.98	5.25	0.087
Overall[b]	5.08	4.92	5.53	5.00	5.15	0.087

[a] N = 225 observations for each sensory value.

[b] Means observation based upon a 7 point hedonic scale (7= liked extremely; 1 = disliked extremely).

REFERENCES

Acton, J.C., Dick, R.L. and Torrence, A.K. 1979. Turkey ham properties on processing and cured color formation. Poultry Sci. 58:843.

Anonymous. 1976. Ham made from turkey. Food Eng. 48(3):26.

AOAC. 1980. "Official Referernce Methods of Analysis." 12 ed. Association of Offical Analytical Chemists, Washington, DC.

Baker, R.C. and Darfler, J.M. 1981. The development of a poultry ham product. Poultry Sci. 60:1429.

Hasiak, R.J., Chaves, J., Sebranek, J. and Kraft, A.A. 1984. Effect of sodium nitrite and sodium erythorbate on the chemical, sensory and microbiological properties of water-added turkey ham. Poultry Sci. 63:1364.

Hornsey, H.C. 1956. The colour of cooked cured pork. 1. Estimation of nitric oxide-heme pigments. J. Sci. Food Agric. 7:534.

Krause, R.J., Ockerman, H.W., Krol, B., Moerman, P.C. and Plimpton, R.F.Jr. 1978. Influence of tumbling, tumbling time and sodium tripolyphosphate on quality and yield of cured hams. J. Food Sci. 43:853.

SAS Institute Inc., SAS User's Guide: Statistics, 1982 Ed. Cary NC: SAS Institute Inc., 1982.

Schmidt, G.R. 1977. Why massage or tumble? Meat Industry. 11:40.

Siegel, D.G., Theno, D.M., Schmidt, G.R. and Norton, H.W. 1978. Meat massaging: The effects of salt, phosphate and massaging on cooking loss, binding strength and exudate composition in sectioned and formed hams. J. Food Sci. 43:331.

Tarladgis, B.G., Watts, B.M., Younathan, M.T. and Dugan, L. Jr. 1960. A distillation method for quantitative determination of malonaldehyde in rancid foods. J. Amer. Oil Chem. Soc. 37:44.

USDA. 1979. Composition of Foods: Poultry products; raw, processed, prepared. U.S. Dept. of Agr., Agr. Handbook, No. 8-5.

USDA. 1983. Composition of Foods: Pork products; raw, processed, prepared. U.S. Dept. of Agr., Agr. Handbook, No. 8-10.

USDA. 1984. Livestock and poultry Outlook and Situation Report. Dec. 1984.

MICROBIOLOGICAL QUALITY AND STORAGE STABILITY OF WATER-ADDED HAM BLENDS CONTAINING PORK AND TURKEY THIGH MEAT

C.M. CHEN AND K.W. JONES

SOUTH DAKOTA STATE UNIVERSITY, BROOKINGS.

ABSTRACT

One hundred and eighty two Kg of sectioned and formed ham were prepared using pork and turkey thigh meat blends. Treatments consisted of the following ratios of boneless pork ham to turkey thigh meat: 1) 100:0; 2) 75:25; 3) 50:50; 4) 75:25; 5) 0:100. Meat was vacuum tumbled, smoked and cooked until an internal product temperature of 72 ^{o}C was attained. Product was sliced, vacuum packaged and stored at 5 ^{o}C for 9 weeks. No change in nitroso-pigment content was observed up to 6 weeks of storage time. Nitroso-pigments decreased ($P < .05$) at the 9 week storage time. Treatment 5 exhibited higher ($P < .05$) nitroso pigment values throughtout the 9 weeks of storage. No differences were observed in pH values due to storage. TBA values increased slightly ($P < .05$) with storage time. There was no significant difference observed among treatments in aerobic and anaerobic plate counts during the 9 week storage period.

INTRODUCTION

The spoilage of cured meat products is normally slowed by the use of nitrite and low temperature storage in combination with packaging. However, the actual storage life of cured meat products is influenced by several factors which include the level of unsaturated fatty acids (rancidity development) in raw meat, spoilage organisms that survive after heat processing, contaminations after heat processing, temperature of storage, packaging conditions, etc.

The oxidation of meat and meat products and the development of rancid flavors are partially due to the presence of unsaturated fatty acids. Allen and Foegeding (1981) reported that the most important rancidity factor involving muscle lipids were the polyunsaturated fatty acids. Poultry meat contains a higher proportion of polyunsaturated fatty acid than the fats from red meat (USDA, 1979,1983). Generally speaking, the higher degree of unsaturated fatty acids, the more sensitive the lipid system is to oxidation.

The predominent bacteria in vacuum-packaged ham has been reported to be lactic acid bacteria (Allen and

Foster, 1960; Kempton and Bobier, 1970; Steele and Stiles, 1981). The higher lactic acid bacteria and lactobacilli counts were detected in product that developed the lower pH (Paradis and Stiles, 1978; Steele and Stiles, 1981).

The objective of the present study was to investigate effects of storage time on the bacterial levels, pH, TBA value and color change of hams made from turkey and pork blends.

Materials and Methods

Processing procedure. One hundred and eighty two kilograms of fresh pork hams and the same amount of frozen boneless, skinned turkey thigh meat was purchased from a regional meat packer and turkey processor. Trimming of pork hams involved the removal of excess subcutaneous and intermuscular fat and connective tissue. The hams were sectioned into chunks averaging 8 to 10 cm in diameter. Five different ham formulations were prepared as shown in Table 1.

The curing ingredient was composed of sugar (0.12%), sodium nitrite (not more than 0.75%), propylene glycol (0.5%) and salt (98.63%). Tumbling was accomplished with a VORTRON vacuum tumbler (Model #250, E-Zuber Engineering, INC., Minneapolis, MN) The meat was vacuum tumbled intermittently at 5 ^{o}C for 7 hours. The intermittent tumbling cycle consisted of alternating rotation (30 min) and rest (5 min) periods. Following the seven hour tumbling period, all hams were stuffed into fibrous casing to form approximately 2.5-3.5 Kg hams.

Cooking procedure. Hames were thermally processed in a FESSMANN, TURBOMAT 3000 Smokehouse (U.S. Supplier, T.W. Kutter, Inc., Avon, MA) equipped with a microprocessor.

The cured, raw product was processed in the smokehouse in accordance with the schedule shown in Table 2. After an internal product temperature of 72°C was attained, hams were removed from the smokehouse and water showered until the internal temperature reached 40°C (100°F) and held in a cooler overnight. One ham from each batch was randomly chosen and sliced into one inch pieces. The slices were vacuum-packaged in a high barrier film, and stored in cardboard boxes at 5°C until analyses. After 1, 3, 6 and 9 weeks of storage, samples were evaluated for TBA, pH, color values and bacterial numbers.

Color Measurement. The method by Hornsey (1956)was used to determine nitric oxide heme pigments and total pigment.

Thiobarbituric Acid (TBA) Analysis. The method of Tarladgis et al. (1960), a distillation for the quantative determination of malodaldehyde in rancid foods, was used to determine TBA values. Slurries were prepared from 10 g samples, and absorbance values were read at 538 nm.

pH Test. Ten gm of sliced meat sample was combined with 100 ml distilled water for one minute in a Waring blender jar. The pH was measured on a Corning Model 12 research meter.

Microbiological analysis. Randomly selected samples were opened aseptically and a section was removed by slicing

across the center of the stack of slices with a sterile knife. The sample was adjusted to 25 g by trimming along the edge of the strip and blending for two minutes with 225 ml of sterile diluent in a sterile Waring blender jar. Appropriate dilutions were made, transferred to petri dishes, and poured with Standard Plate Count Agar. Plates were incubated aerobically at 32 °C for 48 hours and at 5 °C for 10 days. Anaerobic plates were incubated in a Gas Pak 150 System (Becton, Dickinson & Co., Cockeysville, MD) at 32 °C for 48 hours. Results from plate count determinations are reported as logarithm of bacterial numbers per gm of tissue.

Statistical Analysis. The main experimental design of this study was a random block design with five treatments and three replications. Analysis of variance, means and standard errors were used to determine differences between treatment means in this study. The significance of the effect of turkey meat levels, storage time and interactions were based on individual F-tests made on each of the comparisons. The statistical Analysis System (SAS, 1982) was used to calculate means, standard errors and interactions.

RESULTS & DISCUSSION

Color

Figure 1 illustrates the significant interaction effect of treatments and storage time measured by nitroso pigment content. Turkey ham (treatment 5) exhibited higher nitroso pigment levels than other treatments throughout the 9 weeks storage period, however the magnitude of this difference decreased with time. This affect is due to the higher myoglobin content in turkey muscle which has also been observed by Baker and Darfler (1981). No major differences in nitroso pigment content were observed between treatments 1 through 4 over storage time. However, there was a trend toward decreasing pigment values as storage time increased as would be expected. This fading of cured meat color is well documented in the literature and is affected by bacterial growth, lipid oxidation, packaging conditions and light. However, lipid oxidation changes in this study were very minor.

A significant interaction between treatments and storage time was also observed for total pigment levels and is shown in Figure 2. However, those results are much more random in nature than were the nitroso pigment interactions.

pH value

The results of pH data are presented in Tables 3 and 4. Treatment 1 (pork ham) had a lower ($P < 0.01$) pH than all other treatments. No differences were observed between treatments 2 and 3 and between 4 and 5. Generally, the pH value of hams increased as levels of turkey meat in the formulation increased. This was a result of turkey thigh meat having a higher pH value than lean boneless raw ham. No differences in pH were observed as a result of storage time. Figures 3 and 4 illustrate the cumulative effect of how pH was affected by treatment and storage time. In this study, pH did not appear to be affected by microbial load. These results agree with those of Steele and Stiles (1981) who, reported that pH was not a reliable indicator of microbial load.

TBA value

TBA values are reported in Table 5. The data indicated that all treatments had very acceptable TBA values, less than 1 mg malonaldehyde per 1000 gram sample, over the nine weeks of storage in this study. This data is in agreement with that of Younathan and Watts (1959); Zipser et al. (1964) and Hadden et al. (1975) who stated that nitrite effectively inhibits the rate of oxidative

rancidity (as measured by TBA values) in cured meat products. Lin et al. (1980) and Uebersax et al. (1978) reported vacuum packaging inhibits the oxidation of lipids and minimizes the development of rancid flavors. The low TBA values in this study would be expected since the nitrite-cured products were vacuum packaged during storage.

A significant interaction of means for TBA values was observed and not unexpected. This interaction between treatments and storage time is plotted in Fig. 5. Within storage time, means were not different at 1 week. However, at the 6 and 9 weeks storage time, the use of lower levels of turkey meat resulted in significantly lower ($P < 0.05$) TBA values. Higher levels of turkey meat did not result in higher TBA values throughout the entire storage time.

TBA values did not increase steadily with storage time in this study. According to Tarladgis et al. (1960), malonaldehyde does not accumulate as a stable end product of fat oxidation. This may account for the observed increase and subsequent decrease in TBA values. Although the TBA values are significantly affected by storage time in statistical analyses, the absolute differences are of little practical value since their magnitude is quite low. Change et al. (1961) reported that off odors and rancid

flavors can be detected for most tissues when the TBA number is 0.5 - 1.0. No off odors or flavors were detected in this study after 9 weeks of refrigerated storage.

Microbial counts

Statistical analysis of the microbiological data indicated that the two major sources of variation in the standard plate count (mesophiles), the anaerobic count and the aerobic count of the sectioned and formed hams were the levels of substituted turkey meat and storage time (Table 6 - 7).

The effect of meat source on the bacterial counts of hams is shown in Table 6. There was no significant difference among treatments in aerobic and anaerobic counts due to different levels of pork and turkey thigh meat blends. As would be expected, the aerobic and anaerobic counts increased with storage time (Table 7). These trends are shown in Fig. 6-8. These data agree with those of Langlois and Kemp (1974), who reported that increased storage time resulted in increased numbers of microorganisms in meat.

Analysis of variance results of aerobic counts (incubated at 32 ^{o}C, 2 days) showed no significant effects, with an average count of $1.4 * 10^{7}$ cells per

gram after 6 weeks of storage. Storage for 9 weeks resulted in a mean total aerobic count of $6.5 * 10^8$ cells per gram (Fig. 6). The number of bacteria in samples incubated at 5 °C was much smaller (average $8.8 * 10^2$) than the samples incubated at 32 °C after 9 weeks of storage. Bacterial counts of vacuum-packaged ham incubated at 32 °C under anaerobic conditions at various storage times are shown in Fig. 8. Anaerobic counts were $1.3 * 10^7$ cells per gram after 9 weeks of storage.

CONCLUSIONS

The data observed in this study indicated that vacuum-packaged ham was acceptable up to at least 9 weeks of refrigerated storage. Minor color fading occured after 9 weeks of storage time. The pH value was within the pH 6.0 - 6.6 throughout the entire storage time. TBA values were very low, for all treatments through 9 weeks of storage. Anaerobic counts (mesophiles) showed an average count of $1.4 * 10^7$ cells per gram at 6 weeks of storage and $6.5 * 10^8$ cells per gram at 9 weeks of storage. Average anaerobic count was $1.3 * 10^7$ cells per gram at 9

weeks of storage. Steele and Stiles (1981) stated there was no indication that products with total counts as high as 10^9 and 10^{10} per gram were unsafe for human consumption and no obvious sign of spoilage were apparent in the product with these microbial loads. This study suggests that pork, turkey and blended (25:75, 50:50, 75:25) hams have good storage stability under vacuum-packaging conditions.

TABLE 1. TREATMENTS

	PORK		TURKEY	
	(%)	(Kg)	(%)	(Kg)
TREATMENT 1	100	22.7	0	0.0
TREATMENT 2	75	17.0	25	5.7
TREATMENT 3	50	11.4	50	11.4
TREATMENT 4	25	5.7	75	17.0
TREATMENT 5	0	0.0	100	22.7

TABLE 2. THERMAL PROCESSING SCHEDULE

Stage	Time	Smokehouse temperature (C)	Relative humidity (%)	Smoking
1	20 min	50	20	off
2	1.5 hr	55	40	on
3	1.0 hr	60	50	off
4	1.0 hr	65	50	off
5	1.0 hr	70	60	off
6	1.0 hr	75	60	off
7	1.0 hr	80	60	off
8	Until done (*)	85	60	off

* Until an internal product temperature of 72 C was attained.

TABLE 3. EFFECTS OF TURKEY MEAT LEVELS ON pH VALUES OF WATER-ADDED HAMS.

	Treatments (Pork : Turkey)					
	Trt 1 (0:100)	Trt 2 (75:25)	Trt 3 (50:50)	Trt 4 (25:75)	Trt 5 (0:100)	S.E.
pH values	6.135[a]	6.305[b]	6.338[b]	6.504[c]	6.505[c]	0.01

a,b,c. Means in same row with a different superscript are significantly different ($P < .01$).

TABLE 4. EFFECTS OF STORAGE TIMES ON pH VALUES OF WATER-ADDED HAMS.

	Storage Time (Weeks)				
	1	3	6	9	S.E.
pH values	6.631	6.375	6.373	6.352	0.016

TABLE 5. EFFECTS OF STORAGE TIMES ON TBA VALUES[a] OF WATER-ADDED HAMS.

Treatments (Pork : Turkey)	Storage Times (Weeks)				
	1	3	6	9	S.E.
Trt 1 (100:0)	0.225	0.248	0.160	0.126	0.023
Trt 2 (75:25)	0.348	0.293	0.103	0.220	0.023
Trt 3 (50:50)	0.351	0.315	0.163	0.318	0.023
Trt 4 (25:75)	0.271	0.276	0.391	0.336	0.023
Trt 5 (0:100)	0.266	0.248	0.378	0.231	0.023

a TBA values = mg malonaldehyde / 1000g meat.

TABLE 6. EFFECTS OF TURKEY-PORK BLENDS ON MICROBIAL COUNTS OF SECTIONED AND FORMED HAMS.[a]

Treatments (Pork : Turkey)	Mesophiles[b]	Anaerobes[c]	Psychrophiles[d]
Trt 1 (100:0)	10.001	8.145	3.800
Trt 2 (75:25)	8.320	5.288	2.113
Trt 3 (50:50)	8.129	8.194	2.557
Trt 4 (75:25)	6.772	6.157	2.334
trt 5 (100:0)	7.945	5.710	2.050

a Means logarithms of bacterial number per gram of sample.

b Plates (Plate Count Agar, Difco) were incubated aerobically at 32 °C for 48 hours.

c Plates were incubated anaerobically at 32 °C for 48 hours.

d Plates were incubated aerobically at 5 °C for 10 days.

TABLE 7. EFFECTS OF STORAGE TIME ON MICROBIAL COUNTS[a] OF OF WATER-ADDED HAMS.

Storage Weeks	Mesophiles[b]	Anaerobes[c]	Psychrophiles[d]
1	4.15	4.66	1.48
3	6.184	7.276	2.545
6	8.277	7.474	3.276
9	10.951	8.278	3.542

a Means logarithms of bacterial numbers per gram of sample.
b Plates (Plate Count Agar, Difco) were incubated aerobically at 32 C for 48 hours.
c Plates were incubated anaerobically at 32 C for 48 hours.
d Plates were incubated aerobically at 5 C for 10 days.

Figure 1. Interaction effects of turkey meat levels and storage time on nitroso pigment content of water-added hams.

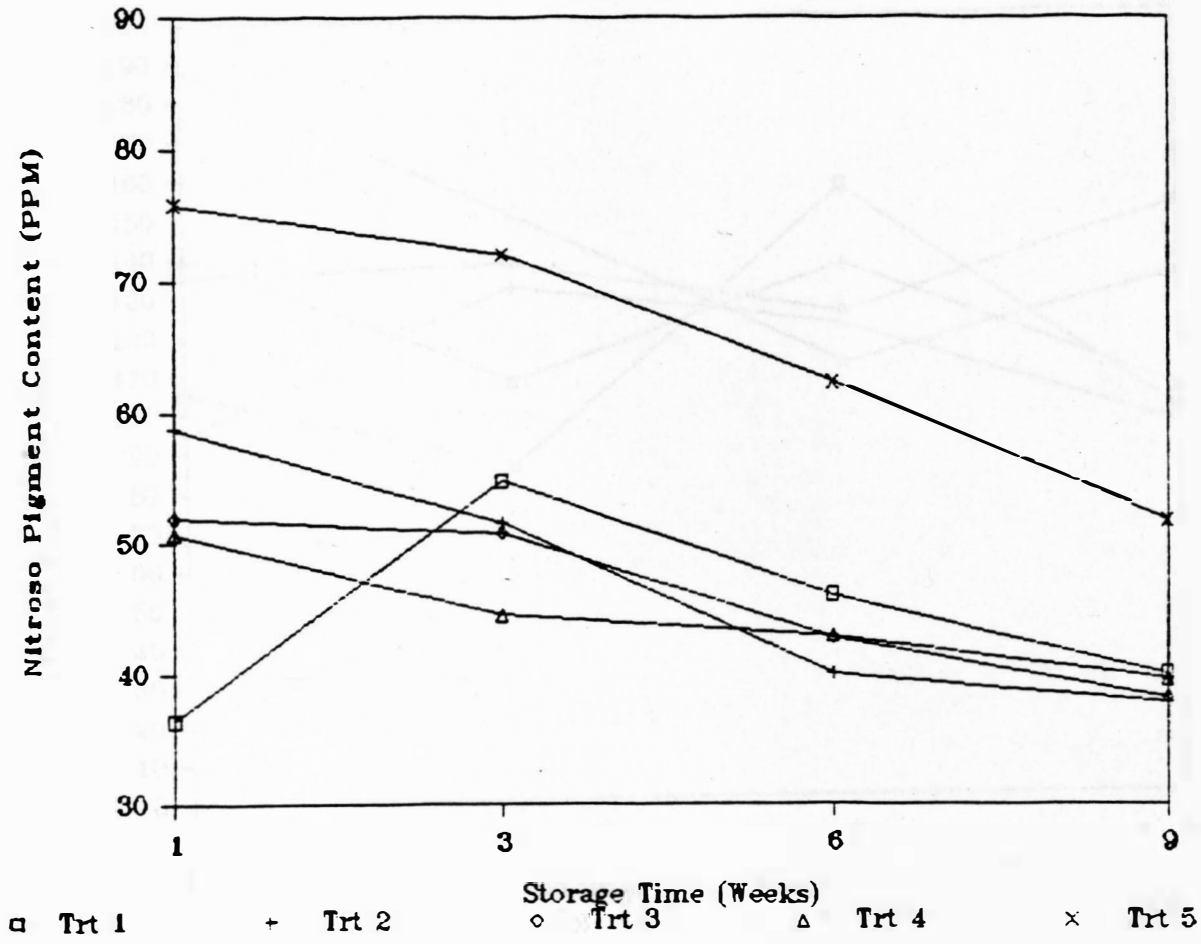


Figure 2. Interaction effects of turkey meat levels and storage time on total pigment content of water-added hams.

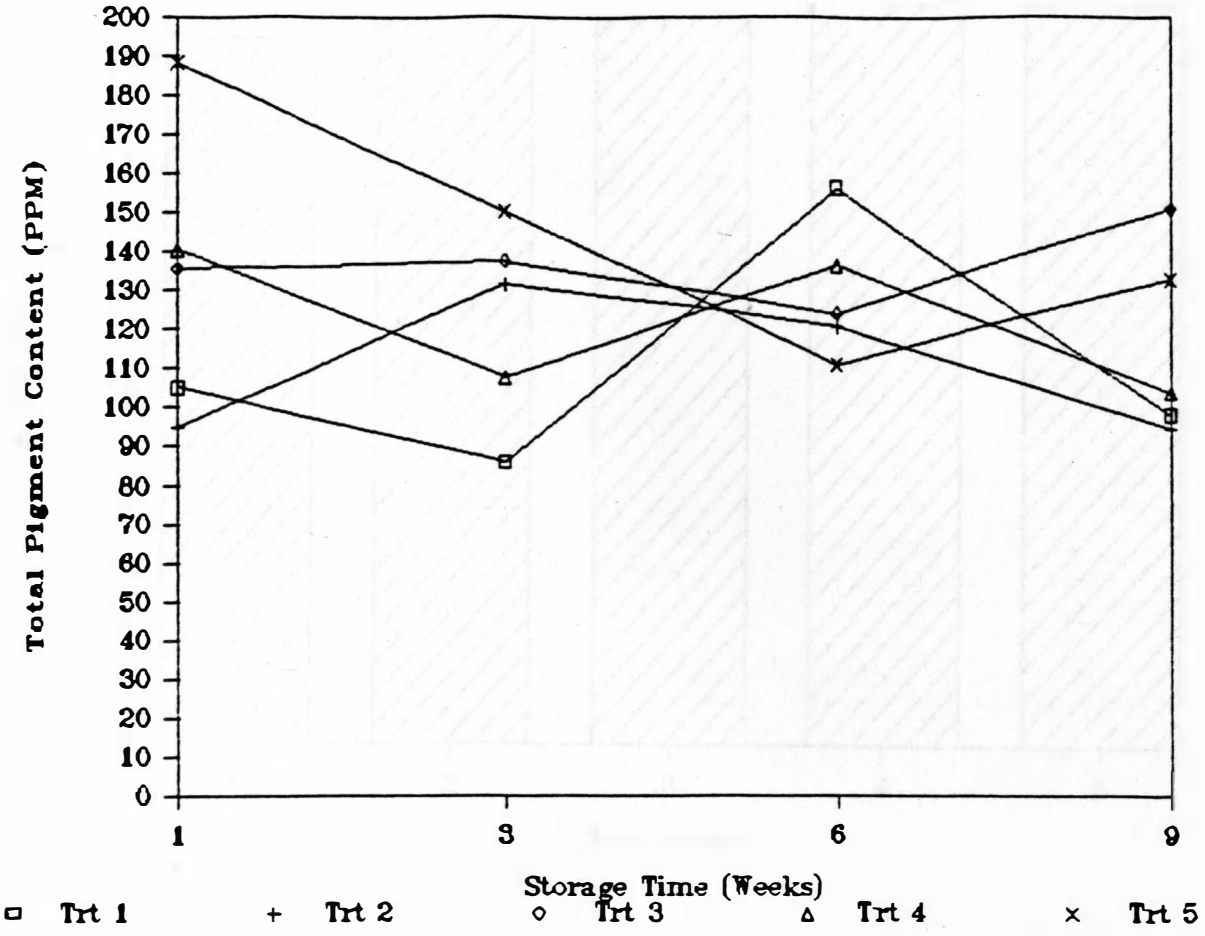


Figure 3. Effect of turkey meat levels on pH values of water-added hams.

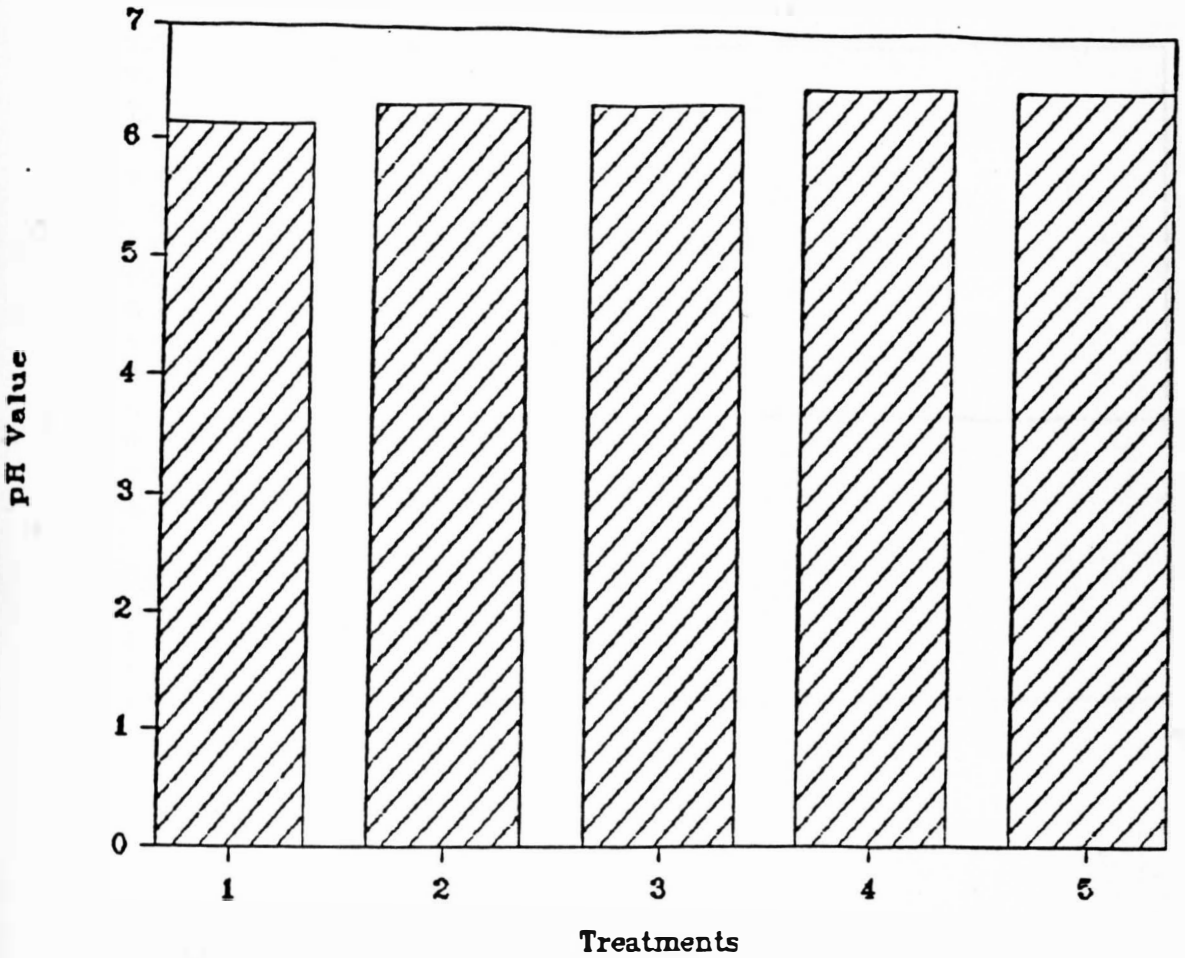


Figure 4. Effect of storage time on pH values of water-added hams.

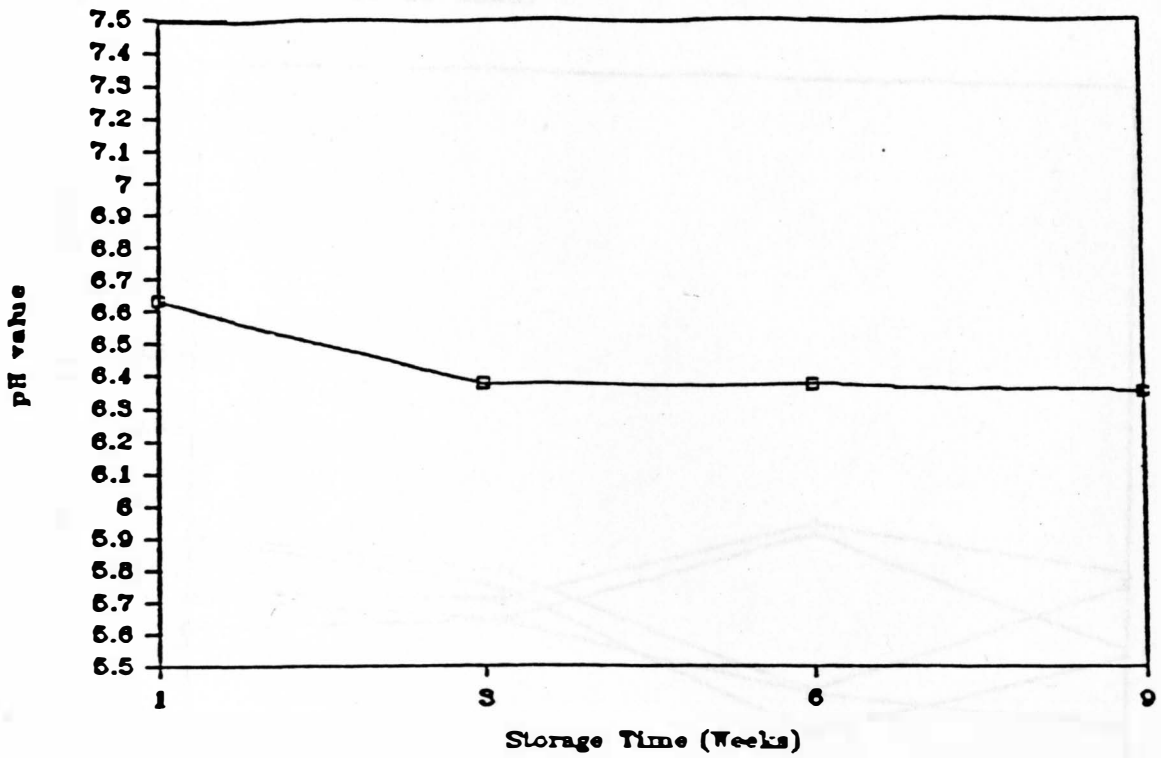


Figure 5. Effect of storage time on TBA values of water-added hams.

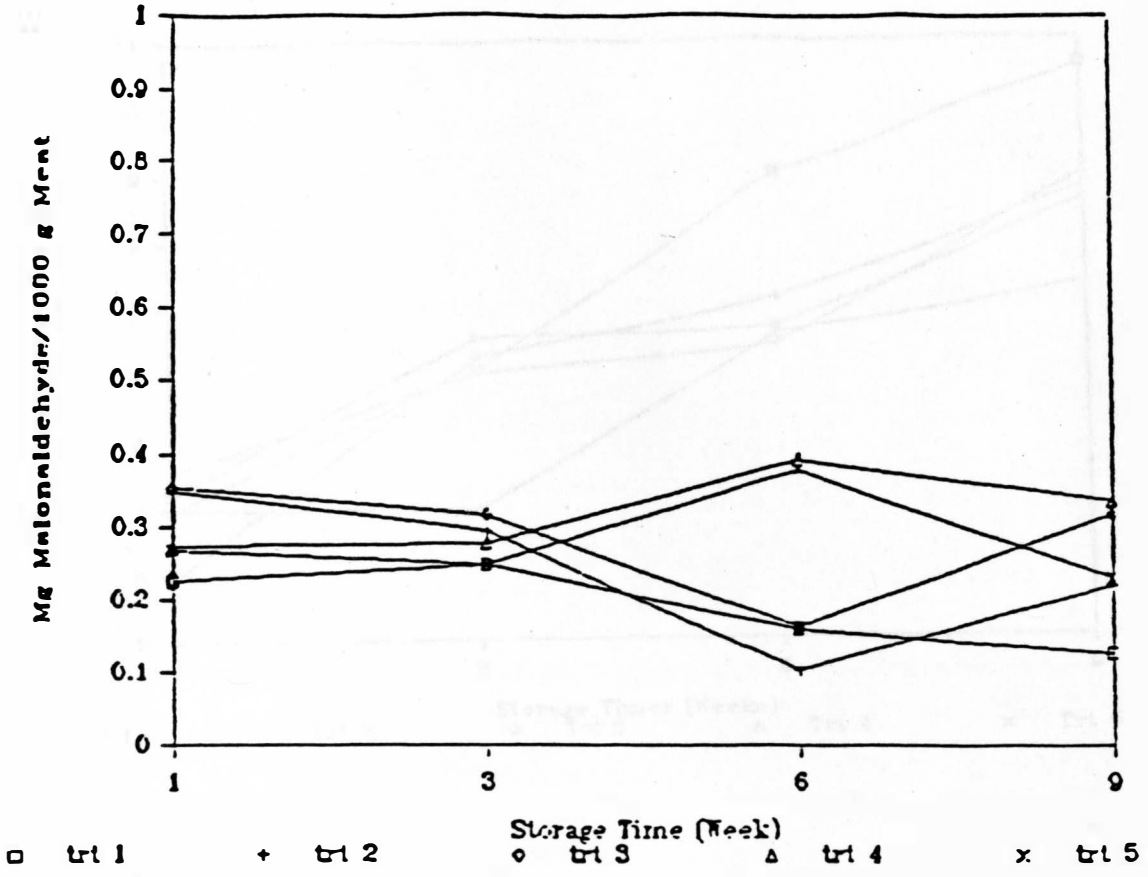


Figure 6. Effect of storage time on standard plate counts (Incubated at 32 C, 48 hours) of water-added hams.

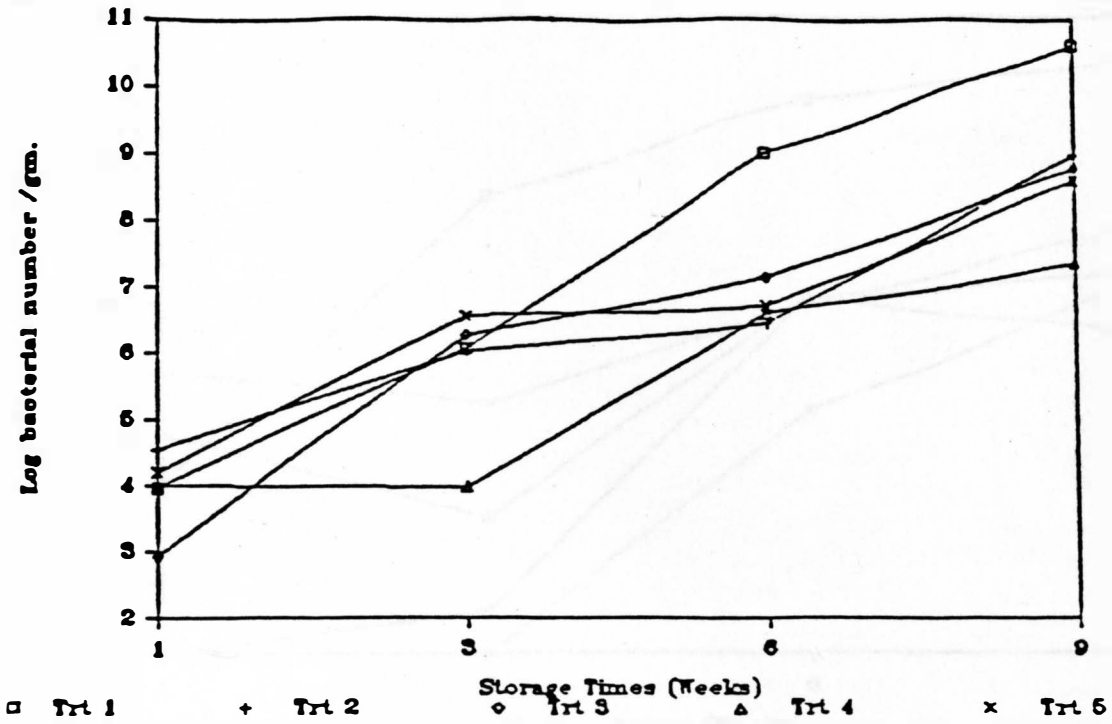


Figure 7. Effect of storage time on psychrophilic counts (Incubated at 5 C, 10 days) of water-added hams.

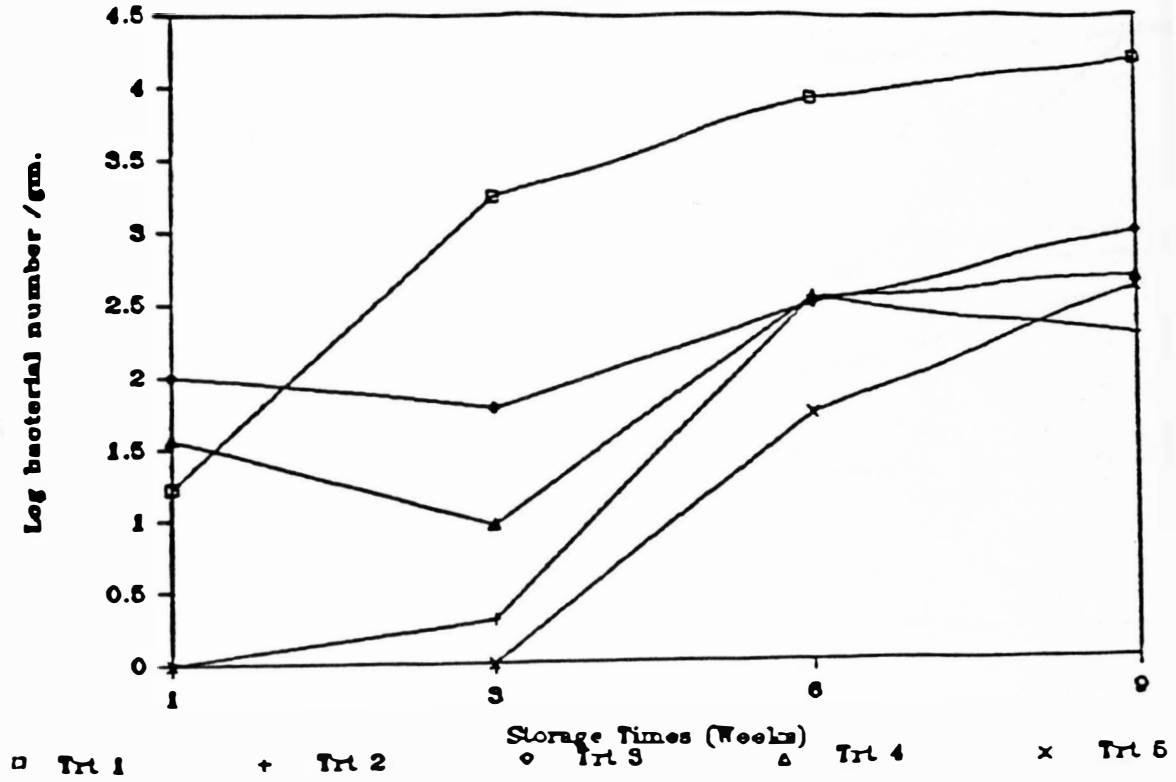
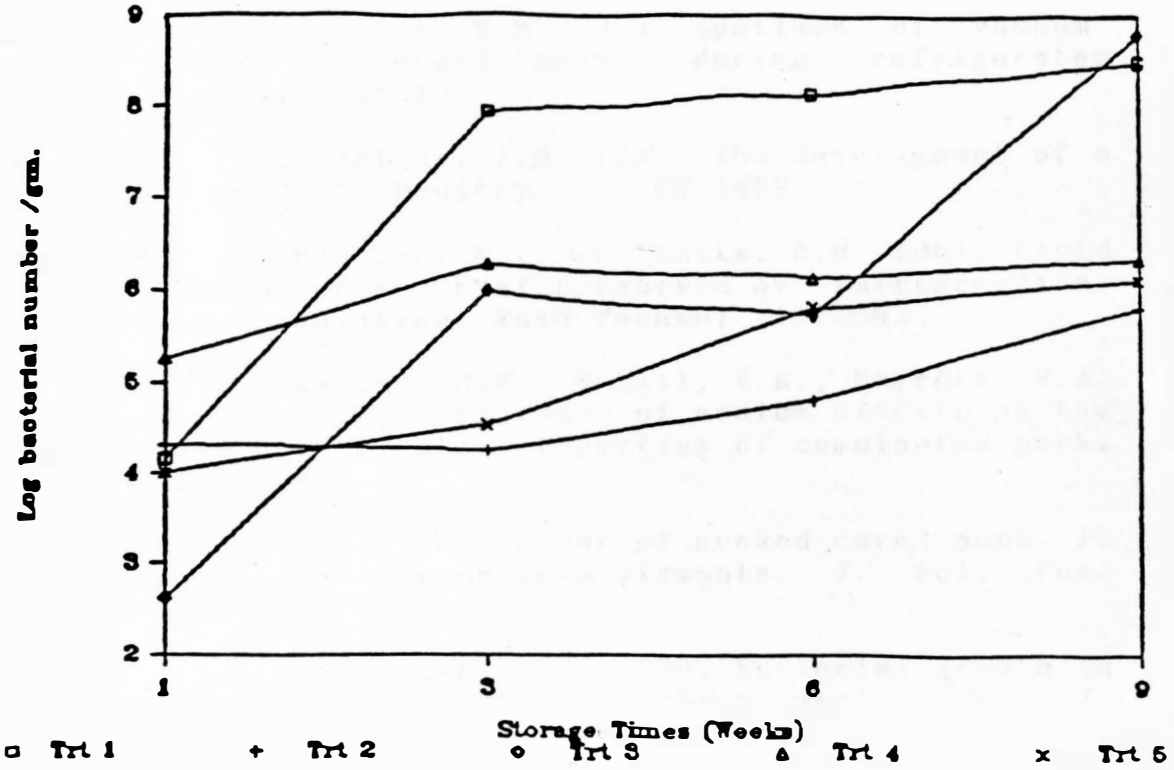


Figure 8. Effects of storage time on anaerobic counts (Incubated at 32 C, 48 hours) of water-added hams.



REFERENCES

Allen, C.E. and Foegeding, E.A. 1981. Some lipid characteristics and interactions in muscle foods - A review. Food Technol. 35(5):253.

Allen, J.R. and Foster, E.M. 1960. Spoilage of vacuum-packed sliced processed meats during refrigerated storage. Food Res. 25:19.

Baker, R.C. and Darfler, J.M. 1981. The development of a poultry ham product. Poultry Sci. 60:1429.

Change, P.Y., Younathan, M.T. and Watts, B.M. 1961. Lipid oxidation in precooked beef preserved by refrigeration, freezing and irradiation. Food Technol. 15:168.

Hadden, J.P., Ockerman, H.W., Cahill, V.R., Parrett, N.A. and Borton, R.J. 1975. Influence of sodium nitrite on the chemical and organoleptic properties of comminuted pork. J. Food Sci. 40:426.

Hornsey, H.C. 1956. The colour of cooked cured pork. 1. Estimation of nitric oxide-heam pigments. J. Sci. Food Agric. 7:534.

Kempton, A.G. and Bobier, S.R. 1970. Bacterial growth in refrigerated, vacuum-packed luncheon meat. Can. J. Microbial. 16:287.

Langlois, B.E. and Kemp, J.D. 1974. Microflora of fresh and dry-cured hams as affected by fresh ham storage. J. Anim. Sci. 38(3):525.

Lin, H.S., Sebranek, J.G., Galloway, D.E. and Lind, K.D. 1980. Effect of sodium erythorbate and packaging conditions on color stability of sliced bologna. J. Food Sci. 45:115.

Paradis, D.C. and Stiles, M.E. 1978. A study of microbial quality of vacuum packaged, sliced bologna. J. Food Prot. 41(10):811.

SAS Institute Inc., SAS User's Guide: Statistics, 1982 Ed. Cary NC: SAS Institute Inc., 1982.

Steele, T.E. and Stiles, M.E. 1981. Microbial quality of vacuum packaged sliced ham. J. Food Prot. 44(6): 435.

Tarladgis, B.G., Watts, B.M., Younathan, M.T. and Dugan, L. Jr. 1960. A distillation method for quantitative determination of malonaldehyde in rancid foods. J. Amer. Oil Chem. Soc. 37:44.

Uebersax, M.A., Dawson, L.E. and Uebersax, K.L. 1978. Physical and chemical composition of meat loaves containing mechanically deboned turekey meat. Poultry Sci. 57:660.

USDA. 1979. Composition of Foods: Poultry products; raw, processed, prepared. U.S. Dept. of Agr., Agr. Handbook, No. 8-5.

USDA. 1983. Composition of Foods: Pork products; raw, processed, prepared. U.S. Dept. of Agr., Agr. Handbook, No. 8-10.

Younathan, M.T. and Watts, B.M. 1959. Relationship of meat pigments to lipid oxidation. Food Res. 24:728.

Zisper, M.W., Kwon, T.W. and Watrts, B.M. 1964. Oxidative changes in cured and uncured frozen cooked pork. J. Agr. Food Chem. 12:105.

APPENDIX

PROCEDURE 1

Thiobarbituric Acid (TBA) Determination

I. Reference:

Tarladgis, B.G., Watts, B.M., Younathan, M.T. and Dugan, L. Jr. 1960. A distillation method for quantitative determination of malonaldehyde in rancid foods. J. Amer. Oil Soc. 37:44.

II. Reagents:

TBA reagent. 0.02 M 2-thiobarbituric acid in 90% glacial acetic acid.

Hcl solution. 1 part concentrated Hcl to 11 parts water (approximately 1 N).

III. Procedure: (Conduct in duplicate)

1. Blend 10 g meat with 50 ml distillated water in Waring blender for 2 min.
2. Transfer quantitatively to Kjeldahl flask by washing with two 25 ml aliquots of 1.0N HCL. Use a repeater pipet with a 25 ml head.
3. Spray a small amount of Dow Antifoam A into lower neck of the flask. Add a few saddle stones to prevent bumping.
4. Assemble apparatus on Kjeldahl distillation apparatus.

5. Distill at highest obtainable temperature.
6. Collect 50 ml distillate.
7. Mix distillate, pipette 5 ml into 50 ml glass-stopped tube, add 5 ml of TBA.
8. Stopper tubes, mix contents, immerse in boiling water bath for 35 min.
9. Use a distilled water + TBA blank and treat like samples.
10. After heating, cool in tap water for 10 min, transfer to cuvette, read O.D. against blank at 538 nm.
11. Multiply reading by factor 7.8 to convert to mg of malonaldehyde per 1000 g of meat.

PROCEDURE 2

Pigment Determination

I. Reference:

Hornsey, H.C. 1956. The colour of cooked cured pork. 1. Estimation of nitric oxide-heam pigments. J. Sci. Food Agric. 7:534-540.

II. Procedure: (Conduct in duplicate)

A. Test for cured pigment (Nitroso hematin)

1. Weigh 10 g of prepared sample and place into beaker.
2. Mix and macerate the sample with solution consisting of 40 ml of acetone and 3 ml of distilled water.
3. Continue mixing the sample for another 5 minutes under reduced light.
4. Filter the solution through Whatman filter paper #1, or equivalent.
5. Prepare your spectrophotometer (with 1 cm cell) at 540 nm wavelength at zero with blank sample containing 80% aceton / 20% water solution.
6. Measure optical density on prepared filtrate at 540 nm and multiply the absorption by 290 to obtain nitroso hematin pigment in p.p.m.

B. Test for total pigments

1. Weigh 10 g of prepared sample and place into beaker.
2. Add 40 ml of acetone, 2 ml of water and 1 ml of concentrated hydrochloric acid.
3. Mix the sample well with acetone solution containing Hcl, cover with watch glass and keep for 1 hour in dark.
4. Filter the solution through Whatman filter paper #1, or equivalent.
5. Prepare spectrophotometer (with 1 cm cell) at 640 nm wavelength at zero with blank sample containing 80% acetone, 2% Hcl and 18% of water.
6. Measure optical density on prepared filtrate with added Hcl, and express total heme pigment at 640 nm and multiply the absorption by 680 to obtain results in p.p.m.

Consumer Taste Panel - Ham

We at South Dakota State University value your opinion in our research program. The products which you are about to sample are sectioned and formed ham slices which have been treated differently. Each treatment number reflects a slightly different formulation. The products are all perfectly wholesome and manufactured under the scrutiny of the South Dakota's State Meat Inspection Program. Products were cured with water, salt, sugar and nitrite. Please mark an "X" in the appropriate block which reflects your honest evaluation of the products. Also please sign the participation consent form on the back of this sheet. Thank you.

Preference Scale	Sample # 251			Sample # 828			Sample # 742			Sample # 964			Sample # 462		
	Flavor	Juici-ness	Overall Accept-ability	Flavor	Juici-ness	Overall Accept-ability	Flavor	Juici-ness	Overall Accept-ability	Flavor	Juici-ness	Overall Accept-ability	Flavor	Juici-ness	Overall Accept-ability
Like Extremely															
? Neutral															
Dislike Extremely															

TABLE 1. THERMAL PROCESSING SCHEDULE

Time	Smokehouse Temperature (°C)	Relative Humidity (%)	Smoke
20 (min)	50	20	off
1.5 (hr)	55	40	on
1.0 (hr)	60	50	off
1.0 (hr)	65	50	off
1.0 (hr)	70	60	off
1.0 (hr)	75	60	off
1.0 (hr)	80	60	off
Until done[a]	85	60	off

[a] Cooked to internal temperature of 72°C.

TABLE 2. ANALYSIS OF VARIANCE FOR COOKING YIELD

Source	df	Sum of Squares	Mean Square	PR > F
Model	6	34.046	5.674	0.182
TRT	4	-	-	0.161
REP	2	-	-	0.264
Residual	8	22.921	2.865	-
Total	14			

TABLE 3. ANALYSIS OF VARIANCE FOR COOKING LOSS

Source	df	Sum of Squares	Mean Square	PR > F
Model	6	34.072	5.678	0.181
TRT	4	-	-	0.160
REP	2	-	-	0.263
Residual	8	22.857	2.857	-
Total	14			

TABLE 4. ANALYSIS OF VARIANCE FOR WATER-ADDED COOKING YIELD

Source	df	Sum of Squares	Mean Squares	PR > F
Model	6	40.423	6.737	0.030
TRT	4	-	-	0.020
REP	2	-	-	0.194
Residual	8	12.506	1.563	-
Total	14			

TABLE 5. ANALYSIS OF VARIANCE FOR MOISTURE CONTENT

Source	df	Sum of Squares	Mean Square	PR > F
Model	14	90.258	6.447	0.0001
TRT	4	-	-	0.0001
REP	2	-	-	0.0001
TRT*REP	8	-	-	0.0001
Residual	15	2.716	0.181	-
Total	29			

TABLE 6. ANALYSIS OF VARIANCE FOR FAT CONTENT

Source	df	Sum of Squares	Mean Square	PR > F
Model	14	47.105	3.364	0.0001
TRT	4	-	-	0.0001
REP	2	-	-	0.0001
TRT*REP	8	-	-	0.0001
Residual	15	1.458	0.097	-
Total	29			

TABLE 7. ANALYSIS OF VARIANCE FOR PROTEIN CONTENT

Source	df	Sum of Squares	Mean Squares	PR > F
Model	14	15.802	1.128	0.0001
TRT	4	-	-	0.0001
REP	2	-	-	0.0004
TRT*REP	8	-	-	0.0001
Residual	15	1.245	0.083	-
Total	29			

TABLE 8. ANALYSIS OF VARIANCE FOR ASH CONTENT

Source	df	Sum of Squares	Mean Square	PR > F
Model	14	3.300	0.235	0.0001
TRT	4	-	-	0.0001
REP	2	-	-	0.3008
TRT*REP	8	-	-	0.0023
Residual	15	0.394	0.026	-
Total	29			

TABLE 9. ANALYSIS OF VARIANCE FOR FLAVOR

Source	df	Sum of Squares	Mean Square	PR > F
TRT	4	71.188	17.797	0.2838
REP	2	22.165	11.083	0.4272
TRT*REP	8	93.559	11.695	0.0001
PLNR	222	654.187	2.946	-
Residual	888	1656.053	1.864	-
Total	1124			

TABLE 10. ANALYSIS OF VARIANCE FOR JUICINESS

Source	df	Sum of Squares	Mean Square	PR > F
TRT	4	46.796	11.699	0.4760
REP	2	17.644	8.822	0.5120
TRT*REP	8	96.862	12.108	0.0001
PLNMBR	222	663.899	2.99	-
Residual	888	1530.741	1.723	-
Total	1124			

TABLE 11. ANALYSIS OF VARIANCE FOR OVERALL ACCEPTABILITY.

Source	df	Sum of Squares	Mean Square	PR > F
TRT	4	50.912	12.728	0.4547
REP	2	17.335	8.668	0.5308
TRT*REP	8	100.949	12.619	0.0001
PLNMBR	222	640.075	2.883	-
Residual	888	1524.538	1.716	-
Total	1124			

TABLE 12. ANALYSIS OF VARIANCE FOR TBA VALUES

Source	df	Sum of Squares	Mean square	PR > F
Model	35	0.993	0.028	0.0001
TRT	4	-	-	0.0001
REP	2	-	-	0.9566
TRT*REP	8	-	-	0.9486
WEEK	3	-	-	0.0100
TRT*WK	12	-	-	0.0001
REP*WK	6	-	-	0.4644
Residual	84	0.696	0.008	-
Total	119			

TABLE 13. ANALYSIS OF VARIANCE FOR pH VALUES

Source	df	Sum of Squares	Mean Square	PR > F
Model	35	3.216	0.091	0.0001
TRT	4	-	-	0.0001
REP	2	-	-	0.2900
TRT*REP	8	-	-	0.0725
WEEK	3	-	-	0.6054
TRT*WK	12	-	-	0.1695
REP*WK	6	-	-	0.2394
Residual	84	1.725	0.020	-
Total	119			

TABLE 14. ANALYSIS OF VARIANCE FOR NITROSO PIGMENTS

Source	df	Sum of Squares	Mean square	PR > F
Model	35	19170.374	547.724	0.0001
TRT	4	-	-	0.0001
REP	2	-	-	0.2444
TRT*REP	8	-	-	0.8252
WEEK	3	-	-	0.0019
TRT*WK	12	-	-	0.0033
REP*WK	6	-	-	0.3553
Residual	84	13225.937	157.451	-
Total	119			

TABLE 15. ANALYSIS OF VARIANCE FOR TOTAL PIGMENTS

Source	df	Sum of Squares	Mean Square	PR > F
Model	35	121974.943	3484.998	0.0001
TRT	4	-	-	0.0007
REP	2	-	-	0.0475
TRT*REP	8	-	-	0.0046
WEEK	3	-	-	0.2029
TRT*WK	12	-	-	0.0003
REP*WK	6	-	-	0.0625
Residual	84	91569.048	1090.107	-
Total	119			

TABLE 16. ANALYSIS OF VARIANCE FOR STANDARD PLATE COUNTS

Source	df	Sum of Squares	Mean Square	PR > F
Model	35	1.6356E+24	4.673E+22	0.369
TRT	4	-	-	0.3527
REP	2	-	-	0.3517
TRT*REP	8	-	-	0.4047
WEEK	3	-	-	0.3440
TRT*WK	12	-	-	0.3608
REP*WK	6	-	-	0.3984
Residual	84	3.6107E+24	4.298E+22	-
Total	119			

TABLE 17. ANALYSIS OF VARIANCE FOR ANAEROBIC PLATE COUNTS

Source	df	Sum of Squares	Mean Square	PR > F
Model	35	5.1115E+18	1.460E+17	0.3507
TRT	4	-	-	0.3226
REP	2	-	-	0.4572
TRT*REP	8	-	-	0.1354
WEEK	3	-	-	0.1634
TRT*WK	12	-	-	0.5777
REP*WK	6	-	-	0.7118
Residual	84	1.1125E+19	1.324E+17	-
Total	119			

TABLE 18. ANALYSIS OF VARIANCE FOR PSYCHROPHILIC PLATE COUNTS

Source	df	Sum of Squares	Mean Square	PR > F
Model	35	3.797E+9	1.084E+8	0.125
TRT	4	-	-	0.0647
REP	2	-	-	0.1119
TRT*REP	8	-	-	0.0249
WEEK	3	-	-	0.4201
TRT*WK	12	-	-	0.7470
REP*WK	6	-	-	0.6771
Residual	84	6.675E+9	7.946E+7	-
Total	119			